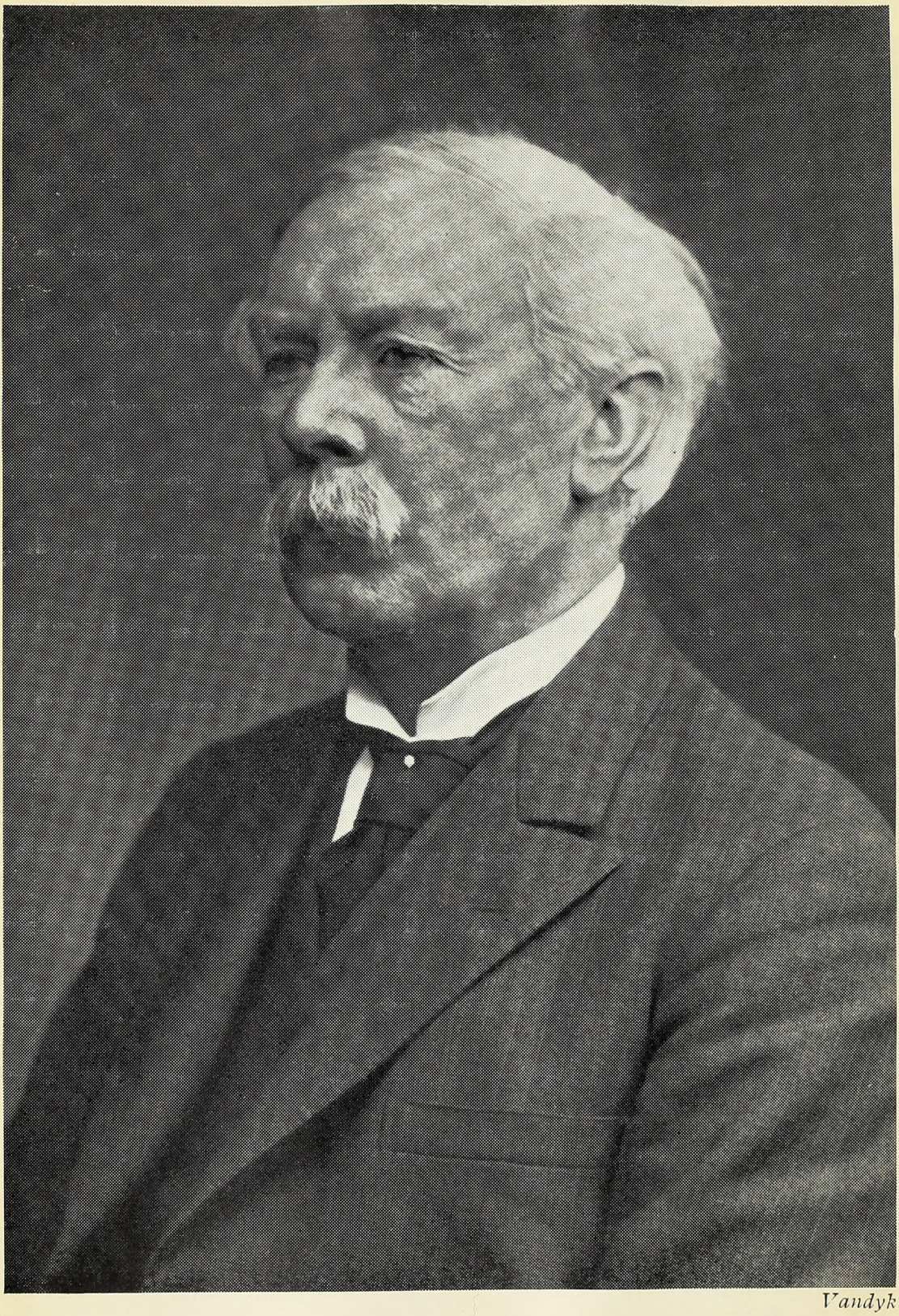


BIOLOGY FOR EVERYMAN



Vandyk

SIR J. ARTHUR THOMSON

BIOLOGY
FOR EVERYMAN

by

J. ARTHUR THOMSON, M.A., LL.D.
Regius Prof. of Natural History, Aberdeen, 1899–1930

Edited by

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VOLUME ONE



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EDITOR'S NOTE

Sir J. Arthur Thomson, whose recent death robbed the world of science of one of its most distinguished biologists, was deservedly celebrated as a man who united a complete mastery of his subject with an intense love of beauty, a keen and sympathetic understanding of the character of animals, and a delightfully lucid prose style. This rare combination of talents rendered him admirably suited for a task that the founder of the House of Dent—the late Mr. J. M. Dent—had very much at heart, namely, the writing of a book that should provide Everyman with a clear, authoritative, and reasonably detailed picture of life in its manifold forms, but that should be free from the technicalities and professional minutiae of the formal textbook.

Sir J. Arthur Thomson entered into the scheme with the utmost enthusiasm, and the publishers willingly assented to his suggestion that the book should be profusely illustrated. A skilled draughtsman was engaged, to work under Sir Arthur's immediate supervision, and a wonderful series of drawings was gradually built up. The composition of the book proceeded steadily, and it became clear that the author intended it to form his *magnum opus*. From his unrivalled store of biological facts he drew all that was most interesting and instructive; and his literary skill and experience enabled him to marshal his material in a form that every reader must find irresistibly attractive.

The manuscript was virtually finished when Sir Arthur died, and only the task of preparing it for the press remained to be accomplished. This is the book, to all intents and purposes, as he left it.

The Editor wishes to acknowledge the valuable assistance given him by Dr. Macgregor Skene, Reader in Botany in the University of Bristol, and by Mr. A. P. Graham, Biology Master at Clifton College.

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E. J. H.

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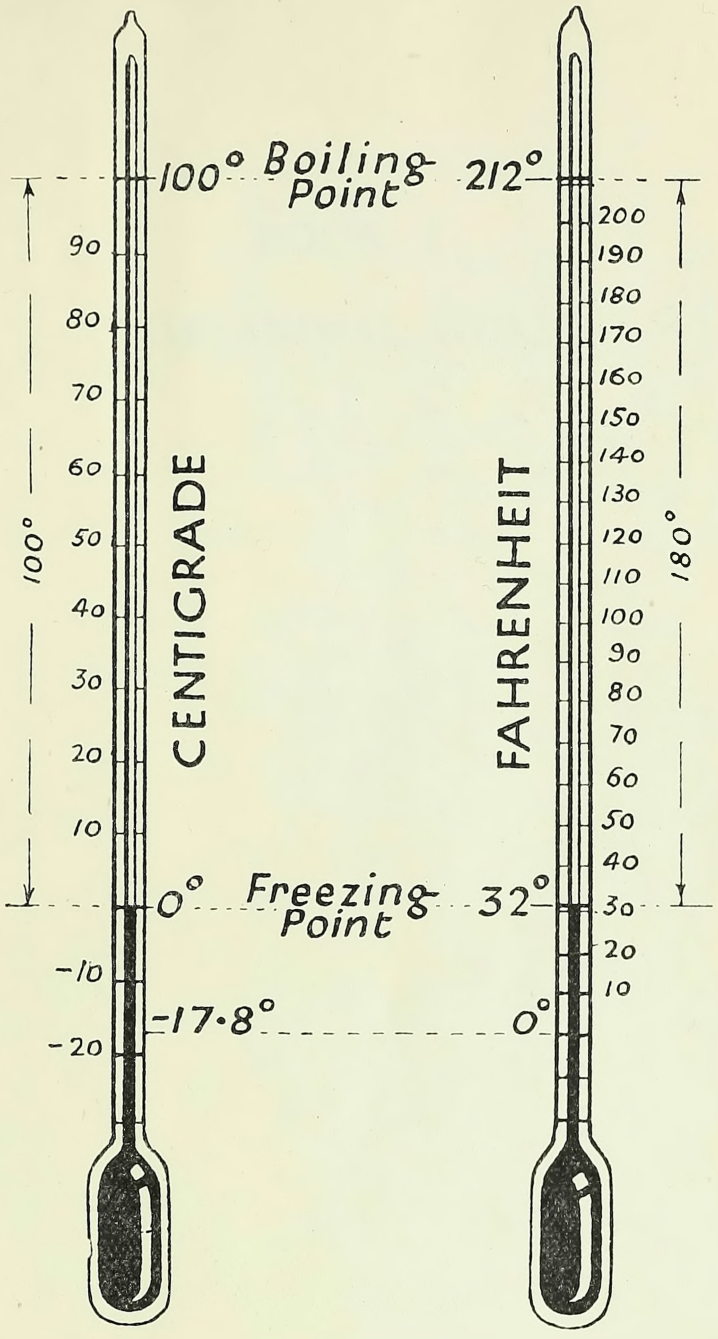
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BOOK I

THE ANIMAL WORLD

CHAPTER I

WHAT LIFE MEANS

Wealth of numbers—Variety of architecture—Diversity of habit and habitat —Hunger and love—Everyday functions of the body: contractility, irritability, nutrition, respiration, excretion, regulation, and the distribution of materials in the body, usually by the blood—Characteristics of living creatures: (1) Ability to make progress; (2) Ability to get things done; (3) Capacity for profiting by experience; (4) The power of growth; (5) The power to multiply; (6) Development in a cycle; (7) Ceaseless changes of living matter; (8) The active living matter in a 'colloidal state,' and (9) Each living creature a self or individuality that lasts for a time.

WEALTH OF NUMBERS. — Without counting the extinct animals, that are known only as fossils entombed in the rocks, there are at least 25,000 named and known different kinds of backboned animals (*Vertebrates*), and 250,000 named and known different kinds of backboneless animals (*Invertebrates*). Some zoologists say that there are half a million different kinds of backboneless animals, but that means including an enormous number of insects not very different from their nearest relatives. Each of these is a distinct *species* or kind, different in some important and more or less constant characters from related species, with which they do not as a rule interbreed. The existence of over a quarter of a million different kinds of living animals shows what possibilities of variety there are in life. But it should be noted that even if we keep to an estimate of 250,000 species, far more than half of this multitude of kinds must be included in the single class of insects. What a contrast to the class of birds, which has only about 14,000 species!

VARIETY OF ARCHITECTURE. — Apart from the enormous number of different kinds of insects, all within one class, and therefore like one another in their foundations, there is an extraordinary range in what may be called animal architecture. What differences there are between the pinhead night-light (*Noctiluca*), that makes the sea sparkle in the short summer darkness, and the whalebone whale, sixty feet long, ploughing its leisurely way in the ocean at the rate of four miles an hour! What differences there are between the sponge and the bird, the starfish and the snake, the earthworm and the butterfly, the snail and the frog, the crab and the cuttlefish, the herring and the barnacle, the skate and the sea-leech that is fastened

to its skin, the coral-polyp and the lark at heaven's gate! It is plain that there are many different styles of animal architecture as well as different buildings in the same style.

DIVERSITY OF HABIT AND HABITAT. — Another impressive fact is the diversity of habit and habitat. There are six great haunts of life: the shore of the sea, the open sea, the depths of the sea, the fresh waters, the dry land, and the air. Within these there are many minor haunts, such as brackish water, caves, mountains, marshes, rivers, deserts, among the branches of the trees, and beneath the surface of the earth. So there are swimming, drifting, running, flying, climbing, burrowing, and other kinds of animals. Some are almost as fixed as plants, others fly at the rate of sixty miles an hour. Some are perched on their neighbours' shoulders; others are unpaying boarders inside their neighbours—in other words, internal parasites. The different kinds of diet are not less varied: there are carnivorous animals, herbivores, insectivores, and omnivores; some are devourers of rotten stuff and others feed daintily on the nectar of flowers; some drink blood and others absorb the digested food in the food-canal of their hosts; a few have green chlorophyll and are therefore able to feed on air and water as plants do, and many have actually got plant-partners living inside them—a very successful alliance. There is astonishing diversity of habit; and it is a great fact of life that almost every corner of land and sea has been peopled by animals. Whenever there is a vacant niche it is seized and tested. Even the new possibilities that man has opened up by his buildings, canals, mines, water-pipes and reservoirs, drains, plantations and stores are soon tested by animal explorers.

HUNGER AND LOVE.—The twofold business of animal life is caring for self and caring for others. On the one hand, there are the activities that secure self-preservation and the satisfying of hunger; on the other hand, there are the activities that are prompted by 'love' in the widest sense, and that secure the welfare of the young. Life swings on these two pivots, 'hunger' and 'love'. On the one hand, there is all the variety of the quest for food, the making of shelters, the parrying of Nature's thrusts; on the other hand, there is all the variety in the winning of mates, the making of nests, the nurture of the offspring.

EVERYDAY FUNCTIONS OF THE BODY.—Since green plants are able, with the help of the sunlight, to feed on air and soil-water, they do not require to move about. For most animals, however, active movement is necessary, since they usually have to hunt for their food. This is the first reason for the locomotor activity of animals, and there are many other reasons, such as chasing mates and avoiding enemies and getting things done. Hence the importance of **contractility** among animals, the function or activity of the **muscles.** What is ordinarily

called a piece of **flesh** is technically a piece of muscle, and it is made up of transparent threads or fibres which do their work by contracting. But if the animal is to move in an effective way, it must be in some measure aware of its surroundings. It must also be able to receive tidings from the parts of its own body and to control these so that they work together in harmony. This is the function of the **nervous system,** often summed up in the word **irritability** or feeling. There are, then, two master-activities of moving and feeling, contractility and irritability; and the other functions of the animal body are in the service of these two.

Nutrition has to do with taking in the food, changing it physically and chemically so that it is made more available, and distributing it through the body—by the circulating blood in most cases. The function of **respiration** has to do with capturing the oxygen which is necessary to bring about the combustion (or oxidation) of the carbon-compounds in, or associated with, the living matter. For all life depends, in its chemical aspect, on ' burnings ' (oxidations or combustions) in the body; and the oxygen captured by lungs or gills or skin or otherwise is needed to ' keep the fire of life burning.' The poisonous gas carbon dioxide,[1] which is formed in all the combustions, has to be got rid of at the lungs or gills or skin or otherwise; and this is the other side of respiration. At bottom, respiration always means ' *plus* oxygen, *minus* carbon dioxide.' One of the many uses of the blood, in backboned animals especially, is to carry the precious oxygen from the place of capture to the place of combustion, and conversely with carbon dioxide.

But the activity of the body must always involve the formation of nitrogenous waste-products, since the most complex carbon-compounds that are always breaking down in the course of life are *nitrogenous* carbon-compounds. The filtering out of these is the function of **excretion**—the great function of the kidneys.

To these three great functions of nutrition, respiration, and excretion there must be added the **regulative function** of the ductless glands, such as those called thyroid, suprarenal, and pituitary. These are glands that manufacture potent ' internal secretions ' or **hormones** which are swept away by the blood and carried to all the parts of the body, playing a very remarkable rôle in harmonizing the other activities. Although they are carried everywhere, the hormones do not influence all the parts through which the blood distributes them. They have particular effects on particular organs, sometimes only one effect on only one organ. They are like keys which can lock or unlock certain doors, but not all doors. Thus there is a hormone called **secretin,** which is carried by the blood from the glandular walls

[1] Formerly, but incorrectly, known as ' carbonic acid gas.'

of the beginning of the small intestine, the part immediately succeeding the stomach, and its particular rôle is to excite the pancreas or sweetbread so that it manufactures more digestive juice which passes into the small intestine to act on the food—dissolving it and changing it chemically. Now this hormone called secretin does not seem to influence any other organ except the pancreas, and, to a slight extent, the liver. Hormones will be discussed further under animal physiology. See HORMONE in INDEX, and ENDOCRINE GLANDS.

In summary, then, there are the following everyday functions, *besides the functions of growing and reproducing*, which are confined to certain times and seasons:

Two Master-Activities

1. **Contractility:** the activity of the MUSCULAR SYSTEM.
2. **Irritability:** the activity of the NERVOUS SYSTEM.

Subsidiary or Auxiliary Activities

3. **Nutrition,** including ingestion, digestion, and absorption: the activities of the ALIMENTARY SYSTEM.
4. **Respiration,** taking in oxygen (O_2), getting rid of carbon dioxide (CO_2): the activity of the RESPIRATORY SYSTEM.
5. **Excretion,** filtering out nitrogenous waste: the activity of the EXCRETORY SYSTEM.
6. **Regulation,** producing hormones: the activity of the ENDOCRINAL SYSTEM.
7. **Distribution,** carrying digested food, gases, hormones, etc., in the blood through the body: the activity of the CIRCULATORY or VASCULAR SYSTEM.

Characteristics of Living Creatures

Life is a particular kind of activity that stands somewhat conspicuously by itself. There are, indeed, chemical processes and physical processes involved in the activities of all living creatures; thus, whenever we move a muscle there is a combustion. Yet when we add up all that we know of these chemical and physical changes that go on, they do not amount to the life of even a simple animal like an amoeba, still less of a higher animal like a bird or a dog, where, moreover, **mind** counts for much. If we took sufficient time and trouble we might be able to give an account of all that each member of an orchestra did with his instrument, but we could not account

for the concert if we left out the conductor and the score. We cannot make sense of the movements of an army unless we know the tactics, and the strategy too. The fact is that every living creature is in some measure an active ' self ' or individuality, and whenever there is an active individuality there is some ' purpose.' There is a ' why ' behind the ' how.' To some extent an animal body works like a machine; but it is much more than an ordinary machine—it is a self-stoking, self-adjusting, self-repairing, self-preservative, self-multiplying machine. In the highest reaches of life it is a self-conscious machine—which is a contradiction in terms! Therefore it is clearer to drop the word machine altogether, provided we keep in mind that some actions of living creatures are very machine-like or automatic. The convenient synonym for ' living creature ' is **organism**; and what we have been trying to suggest is that organisms get far beyond mechanisms.

Living always means give and take, thrust and parry, action and reaction, between the living creature and its surroundings. At one time the living creature acts on its surroundings, moving them, changing them, even devouring them. The earthworm eats the soil, the whale displaces the water, the flying bird presses the air downwards and backwards, and even the passive plant changes the chemical composition of the atmosphere. But we must frankly confess that we are not able to give a definition of that kind of activity which we call living. All that we can do is to make clear what characteristics distinguish living creatures from not-living things, such as stones or stars.

(1) **PROGRESSIVENESS.**—It is always best to seize the bull by the horns, and therefore we begin by saying that living creatures are creatures that change and make progress. They are capable of **evolution.** They are subject to change from generation to generation, for like only *tends* to beget like. Two brothers or two sisters are often very different, and all of them may be very different from either of their parents. They are often like mixtures of their parents' characteristics, getting some features or qualities from the father and some from the mother. In many kinds of living creatures something new is always cropping up; and this **variability** is one of the central secrets of living creatures. We say ' as like as two peas,' but one pea in a pod may develop into a tall, yellow-seeded plant and its neighbour into a dwarf, green-seeded plant. Evolution is going on!

Whatever we think about living creatures, we must include in our thought the fact that all have evolved from very simple forms of life. Flowering plants evolved from flowerless plants, and backboned animals from backboneless animals, and many-celled creatures from one-celled creatures. As all this is very wonderful, and very imperfectly understood as yet, our thought of living creatures must not be

a dull thought, nor a sealed-up thought, it must rather be like a developing seed! In any case, living means the possibility of evolving.

(2) EFFECTIVENESS.—A living creature is a self-preservative, purpose-like agent that gets things done. But how does it differ from a non-living thing that may also do work? A piece of potassium placed on the surface of a pool rushes actively about, fizzing and flaring energetically, but it soon exhausts itself, having changed into caustic potash, soluble in the water. The whirligig-beetle (*Gyrinus*), darting about on the surface of the water and below the surface too, how does it differ from the potassium pill? It commands its course and it does not exhaust itself for a long time. A barrel of gunpowder may prove itself to have great power of doing work or mischief, but it puts an end to itself in its explosion. Animals do not commit suicide in this way; their replies to stimuli are usually self-preservative. No doubt they show wear and tear, but it is their prerogative to *last*—for months or years or stretching cycles of years. But there is more than mere persistence in the activity of organisms.

If a chimpanzee discovers how to insert a short bamboo rod into the hollow end of a longer one, when its problem is to get hold of some fruit beyond its reach outside the cage, we have no hesitation in saying **intelligent behaviour.** We say the same if it piles one box on the top of another, sometimes to the number of four, when its problem is to reach a banana fastened to the roof. But only the higher animals show such clear-cut instances of intelligence. At lower levels, however, there is often a chain of acts that taken together make a piece of **behaviour**; and this linking together of acts so that they lead to a profitable result is characteristic of living creatures. An amoeba, which is one of the simple single-celled animals, has been known to pursue another amoeba, capture it, lose it, pursue it again, recapture it, and finally lose it—and this is on the threshold, at least, of behaviour. When a crayfish is turned upside down it can right itself, but to do so it requires to move particular limbs in a particular order. Mere 'anyhow movements' will not serve. Even among plants there are instances of behaviour, as when the moving tendril answers back to the touch of a support, curves round it, and then twists the part between the support and its origin into a beautiful double spiral which hugs the climber to the support and also serves as an elastic spring, useful when there is a storm. A river does much work in carving out its bed, but it never shows a linking together of acts towards a definite result. A river is active, but it is not an active, purposeful individuality, as is every living creature in some degree.

(3) PROFITING BY EXPERIENCE.—When a bar of iron is hammered hard it is never quite the same again. The axle of a locomotive,

subjected for years to continued strain, may become 'fatigued.' It is altered by its experience. But this is only demonstrable in certain cases among non-living things, namely in cases where there is a complicated internal structure. If the water in a vessel is frozen and then thawed again, we do not know that it is in any way changed by having been solid for a while. But when we pass to living creatures and even parts of living creatures, we find that they have a way of enregistering what they have gone through. A starfish is an animal of low degree and without brains. It has nerve-strands and nervous networks composed of nerve-cells and their fibres, but it has no nerve-centres or **ganglia.** Yet if a starfish is turned upside down, and after a number of trials manages to right itself, it is not quite the same animal after its experience. This is proved by repeating the experiment many times for a week with the same starfish. It becomes able to right itself more and more rapidly; it reduces the number of useless movements. This may be called **learning,** but it is not intelligent learning, for the starfish has no brains. Yet there is a profiting by experience on the animal's part, and this is very characteristic of living creatures. It might be called **organic memory,** but in true memory there is a storing and reviving of mental images of some sort; and in this the mind has a large part to play. Only in animals with well-developed brains dare we speak of **true memory,** but all have organic memory, or the power of enregistering experience. Their past lives on in their present. Even in a plant this can be proved, for if the Venus's fly-trap, that quickly closes its toothed bi-lobed blade when an insect touches its sensitive hairs, be cheated several times in succession with something quite unprofitable, it will cease for a while to give *any* answer-back to the faked booty. It has somehow registered the unprofitable experience, and that modifies what would have been its ordinary answer-back or reaction. But its organic memory is very short, for after it has had a rest it can be cheated afresh!

The same kind of experiment can be made with a sea-anemone. Several times in succession the tentacles on one side can be induced to capture faked food, such as a tiny piece of blotting-paper dipped for a moment in beef juice. But after several profitless experiences of this sort the tentacles throw off the blotting-paper that touches them. After a rest, however, they can be tricked again and will carry the blotting-paper towards the mouth. The sea-anemone has no brain, no nerve-centres; it has only networks of nerve-cells and their fibres; and it is very instructive to notice Professor G. H. Parker's experiment that while the tentacles on one side of the sea-anemone had learned their lesson for the time being, and would not be cheated any more by faked food, those on the other side of the mouth showed

themselves quite innocent and gullible. This shows that an animal without any *central* nervous system is not very much of a *unity* or individuality.

(4) GROWTH.—Linnaeus (1707–78), 'the Father of Botany,' once said: 'Stones grow; plants grow and live; animals grow and live and feel.' This was not so wise as some other things he said, for there is no doubt that plants *feel*; and it is not very clear that stones *grow*. But when Linnaeus spoke of stones growing, he was probably thinking of crystals or minerals. For if a fragment of crystal is dropped into a saturated solution of the same substance, it grows gradually larger before our eyes. The faces of the fragment are soon beset by new crystal units which take form from out of the solution, and these are disposed in a perfectly regular way so that the particular crystalline architecture is preserved. How does this growth of a crystal differ from the growth of a plant or an animal?

A crystal grows at the expense of a solution which contains a substance chemically the same as itself; or, sometimes, out of a solution of a substance which is chemically different but crystallizes in the same form. A green plant, however, grows at the expense of air and soil-water; and an animal grows at the expense of other animals, or by eating plants, or by sucking its mother's milk.

The **growth** of an organism or living creature is an active process; while that of a crystal is passive. The growth of an organism implies that the food is taken in and changed, *often greatly changed*, before it can be used to increase the amount of the living matter, which is what growth always means. But in the case of a crystal the growth is from the outside, by the accretion or fixing on of fresh crystal units. **Accretion** means the depositing of particles on the top of other particles already fixed, as a layer of silver might be deposited on the top of another in the process of electroplating. When a big snowball is rolled along the snow-covered ground it grows by accretion.

Finally, the growth of a living creature is *regulated* by the growth that has already taken place, and this applies to crystals to this extent only, that the new units must be of the same crystalline form. It must be admitted, however, that in the mending of a broken crystal there is *an approach* to the way in which a starfish replaces a lost arm.

(5) MULTIPLICATION.—Some simple people believe that if pearls are kept in a box along with some grains of rice, they will multiply; but this is of course nonsense. Here we face one of the great differences between the living and the non-living: living creatures are able to multiply. Sometimes the **multiplication** (or **reproduction**) is effected *asexually*—by giving off buds, as in the freshwater *Hydra* and the tiger-lily; or, it may be, pieces of the body, as when certain sea-anemones split into two; or when the end of a bladderwort branch breaks

off in the water and starts a new plant. In the vast majority of organisms, however, there is *sexual* reproduction by egg-cells which are fertilized by sperm-cells. This will be discussed later on, but there are two important points to be noted here. The first is that asexual reproduction may be thought of as discontinuous growth. When an organism has grown larger than it is convenient for it to become, it may dispose of its surplus growth by liberating a piece. No doubt some plants may grow larger and larger almost indefinitely, as we see in trees, which have often been compared to colonies of shoots; but this means a particular mode of spreading or arborescent growth. No doubt some animals, like the 'sea-firs' and other zoöphytes (see INDEX), form colonies like little trees, but this abundant budding is rarely practicable except for fixed animals. The point is that over-growth leads on naturally to separating off pieces of the body, and *this* is asexual multiplication. Sexual multiplication by means of special germ-cells or sex-cells is much more economical, as we shall see.

The second point is that the multiplication of living creatures is often prodigiously rapid. Their power of transforming non-living material into living matter is extraordinary. A single slipper animalcule (*Paramecium*), a little infusorian (p. 53) about a hundredth of an inch in length, may give rise in a week to a progeny of a million. Professor T. H. Huxley made the famous calculation that if all the progeny of a single mother green-fly survived and multiplied throughout the summer, there would be at the end a mass of green-flies that would weigh down the whole population of China. Among higher animals the rate of multiplication is naturally much less, for it takes time to develop the complexity of a bird or mammal.

(6) DEVELOPMENT.—This is another characteristic of living creatures. From a fertilized egg-cell there develops a complex organism. Out of the hen's egg there comes a chick. Out of apparent simplicity there arises obvious complexity, and this is certainly one of the wonders of the world of which we have no clear understanding. In a transparent droplet of living matter, lying like an inverted watch-glass on the top of the yolk in a hen's egg, there is the raw material of a chick. All the hereditary qualities lie there. By division after division of the cells or units of living matter, and by arrangements and rearrangements of these, an embryo is gradually developed. Division of labour continues and unification continues; and in twenty-one days there is a chick ready to be hatched. One remembers a verse in one of the Psalms: 'In thy book all my members were written, *which in continuance were fashioned, when as yet there was none of them.*'

(7) CEASELESS CHANGE IN THE BODY.—It is characteristic of living creatures that they are in a state of ceaseless change, always breaking

down and always being built up again, till the time comes when the results of wear and tear are too serious to be met by repair. **Metabolism** is a general word for all the chemical processes that go on in a living body. It includes a great variety of chemical processes—oxidations, reductions, hydrations, dehydrations, and fermentations; but these may be arranged according as they contribute to the upbuilding or the downbreaking of the complex substances involved in or associated with the living matter or *protoplasm*. The constructive or upbuilding processes are summed up in the word **anabolism**; the disruptive or downbreaking processes are summed up in the word **katabolism.** The former is like the winding-up of the clock, the latter is like the running-down. Expenditure of energy in doing work always means katabolism, as is shown by the waste-products formed. An accumulation of potential energy in the form of reserve materials, built up from the food, is the outcome of anabolism. We may picture a continual see-saw between the two sets of changes, but one part of the body may be showing predominant anabolism while another part is showing predominant katabolism.

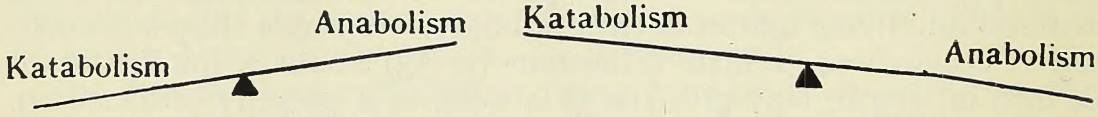


Fig. 1. Anabolism and Katabolism

Protoplasm is a convenient word for living matter. T. H. Huxley defined it as ' the physical basis of life.' It is an intricate mixture of chemical compounds which work into one another's hands, like the members of a firm. (i) There are substances called **proteins,** built up of carbon, hydrogen, oxygen, and nitrogen, usually with a little sulphur, and sometimes with a little phosphorus. As examples may be mentioned: albumen or white of egg, the vitellin or yolk of egg, the casein of cheese, the gluten of wheat, and the stuff that forms the greater part of ordinary red flesh or muscle. (ii) Second in importance are the **carbohydrates,** such as starch and sugar, built up of carbon, hydrogen, and oxygen, with the last two almost always in the *proportions* in which they occur in water (H_2O). (iii) Third, there are the **fats** and **oils,** compounds of carbon, hydrogen, and oxygen, but not in the carbohydrate proportion, or compounds of carbon and hydrogen only. (iv) There are also various carbon-compounds which cannot be included in any of the preceding three groups, and in this miscellaneous lot it may be convenient to include **ferments.** (v) Mineral salts are present in small amounts; and (vi) at least seventy per cent of the whole is water! Living matter, which cannot be isolated by itself, is a mixture of these substances, but of course it is not an ' anyhow '

mixture. We cannot compare it to anything else, unless it be to a business firm, which owes its strength to the way in which the varied gifts of the partners strengthen one another and work for the common good. Now the leading partners in the protoplasm firm are proteins, and from the chemist's point of view life is the breaking-down and building-up (the metabolism) of proteins and associated substances. We do not know of any living that does not imply the upbuilding and downbreaking of proteins.

(8) LIVING MATTER A COLLOID.—Another characteristic of organisms is that the physical basis of life is in a **colloidal state.** This means that innumerable ultra-microscopic particles, or it may be unmixing droplets, are suspended in a fluid medium; and the chief importance of this state of matter is the large surface which the particles present to surrounding influences in the fluid. Most substances, even gold, can be made to assume a colloidal state, but many carbon-compounds assume it very readily. The colloidal state may be contrasted with a crystalline state, where the particles are more or less rigidly fixed in a precise order; or with an ordinary solid state, where the particles are more or less fixed, but not with regimental precision; or with a uniform fluid, such as water, where the component molecules glide freely over one another; or with a simple solution, such as salt and water, where ions of sodium and chlorine move freely about among molecules of water. It is characteristic of colloids that they tend to pass from a ' gel ' state, like jelly, where free movements are restricted, to a ' sol ' state, like a solution, where there is free movement of particles. Or the change may be in the other direction, from ' sol ' to 'gel.' An active white blood corpuscle, always changing its shape, is in a ' sol ' state; but a nerve-cell is in a ' gel ' state.

(9) POWER OF PERSISTENCE.—The last characteristic of living creatures that we shall mention is their power of remaining the same in spite of ceaseless change. A piece of iron, left out in the rain, soon rusts. It changes, but it changes into something different from iron, it becomes rust or hydrated oxide of iron. A granite block on the hill-side slowly weathers; it changes into other things, such as clay. A barrel of gunpowder may change very energetically, but when it has finished its work or mischief there is no more gunpowder.

But the secret of the living creature is that it does its work and yet retains its sameness. There is wear and tear, but the destructive effects can be evaded for a longer or shorter time. The winged may-fly may be literally the creature of a day; the elephant may live a hundred years: but the duration of life is not the characteristic feature. What distinguishes the living creature is its power of being a going concern for some time, at least. It can balance its accounts. Its clock runs down, but it can wind it up again. It is quite possible

that the first organisms lived for only about twenty-four hours, that they flourished in the sunshine, multiplied in the evening, and died in the chill of their second night, but they had crossed the Rubicon! They were solvent, going concerns, though only for a very short time.

There is something more. One kind of living creature is different from another living creature. Each is an individuality; itself, and no other. Each is what is called 'specific'; that is to say, from the chemist's point of view, it has a particular kind of metabolism. In many cases it has been shown to have a particular kind of protein all to itself. In many cases it has been shown to have particular details of microscopic structure that no other creature has. Sometimes the naturalist can identify a fish from a single scale or a bird from a single feather. And in remaining the same in spite of ceaseless change, the living creature does not merely remain the same in a general way: it retains its **specificity**, its 'individuality.' It remains, as long as it can, *itself and no other*.

So let us sum up the characteristics of living creatures, arranging them in three groups of three:

I.
(1) Ability to evolve, to change from generation to generation and make progress.
(2) Ability to get things done effectively.
(3) Capacity for profiting by experience.

II.
(4) Power of growth.
(5) Power to multiply or reproduce.
(6) The power of developing in a cycle.

III.
(7) Ceaseless changes or metabolism of living matter.
(8) The active living matter is in a colloidal state.
(9) Persistence of bodily integrity and individuality for a time.

It is the harmonious combination of these characteristics that makes a living creature.

CHAPTER II

BIRD'S-EYE VIEW OF THE ANIMAL KINGDOM

The Backboned Sub-Kingdom: MAMMALS or milk-giving animals with hair—BIRDS, or feathered bipeds—REPTILES, cold-blooded, scale-covered creatures—AMPHIBIANS, betwixt and between—FISHES, scaly, gill-breathers, with fins. **The Backboneless Sub-Kingdom:** MOLLUSCS, such as cuttles, snails, and bivalves—Jointed-footed animals or ARTHROPODS, such as spiders, insects, centipedes, crustaceans—Prickly-skinned animals or ECHINODERMS—The higher RINGED WORMS or ANNELIDS—The LOWER WORMS—STINGING ANIMALS—SPONGES—Unicellular animals or PROTOZOA—As regards classification—Homologous and analogous—Beginnings—Form in the animal world.

THE order to be followed in this book is from the lowest animals to the highest, for that is the order in which they made their appearance upon the earth. This introductory bird's-eye view will, however, survey the animal kingdom in the opposite direction, from the more familiar higher animals to the less familiar lower forms. Therefore the first place is given to the backboned animals, or Vertebrates, though it must be kept in mind that for *millions* of years after life began upon the earth there were only backboneless animals, or Invertebrates.

BACKBONED OR VERTEBRATE ANIMALS

Zoologically considered, we ourselves are **Mammals,** so we must rank mammals as the highest class. In a broad way it may be said that mammals are four-footed, warm-blooded, hair-covered, milk-giving animals. As T. H. Huxley suggested, they may be ranked on three levels:

		III
	II	Placentals
I	Marsupials	
Egg-laying		

(1) the primitive duckmole and spiny ant-eater, which lay eggs; (2) the pouch-possessing marsupials, like the kangaroo, which bring forth their young so helpless that they cannot even suck; and (3) the ordinary (placental) mammals, such as carnivores, insectivores, herbivores, and monkeys.

Almost as high as mammals on the scale of being are the **Birds,** feathered bipeds, warm-blooded and egg-laying. At a lower level,

but with great diversity, is the class of **Reptiles**—crocodilians, tortoises, lizards, and snakes, and a multitude of extinct types, from amongst which both birds and mammals seem to have had their origin. Reptiles are cold-blooded, small-brained, scale-covered animals—mostly grovelling on the earth. Yet there used to be flying dragons.

Very different from reptiles, nearer to fishes indeed, are the **Amphibians,** betwixt-and-between animals that made the transition long ago from water to dry land—a very important step which they usually recapitulate in every generation. Here come frogs and toads, newts and salamanders, cold-blooded and clammy, with naked skins. Amphibians were the first animals to have fingers and toes, breathing nostrils, true lungs, vocal cords, and a movable tongue.

Linked closely to the amphibians are the **Fishes,** highly successful in their mastery of the water and in their peopling of all the seven seas. The linkage to the amphibians is partly through the strange mud-fishes (or *Dipnoi*), which have lungs as well as gills, just as is the case with tadpoles. The limbs of fishes are represented by the *paired* fins, which have not yet attained to the possession of digits. They are chiefly of use for balancing, the usual swimming organ being the very muscular tail region. The body is covered with scales formed from the under-skin (or *dermis*), not, as in reptiles, from the outer skin (or *epidermis*). There are very abundant goblet-cells in the skin, which produce the secretion that makes fishes so slippery. All fishes have gills throughout their life, while most amphibians lose them as they put on adult characters. A few fishes, however, are helped to breathe by a swim-bladder, and this becomes a genuine lung in the mud-fishes or *Dipnoi*.

Mammals, *birds*, *reptiles*, *amphibians*, and *fishes*: these are the five great classes of backboned animals or Vertebrates, which have been recognized for two thousand years. But there are some old-fashioned primitive forms below the level of fishes. These are the round-mouths or *Cyclostomes* (jawless, limbless, scaleless), the lancelets (*Amphioxus*) which are veritable pioneer Vertebrates, and the sea-squirts or *Tunicates* which start well-equipped with backboned characters, but usually end as degenerate nondescripts. Lowest of all, linking Vertebrates back to worm types, are the gut-breathers or *Enteropneusts*, e.g. *Balanoglossus*.

Backboneless or Invertebrate Animals

The highest backboneless animals, at any rate as regards brains, are the cuttlefishes, like the octopus, the squid, and the pearly nautilus. In spite of such names as cuttlefish they are far away from true fishes;

they form one of the classes of **Molluscs.** Here too, in another class, come the snails and slugs, both in water and on land—the *Gastropods*; such as periwinkle and whelk, limpet and ear-shell. Also molluscs, but at a lower level, are the headless bivalves or *Lamellibranchs*, such as cockles and mussels, oysters and clams.

In a typical mollusc the skin always forms a substantial shell of calcium carbonate (limestone), which is added to along its free edge as the animal continues to grow. The body is not divided into segments and there are no limbs of any kind. On the under-surface of the mollusc there is usually a strong development of muscle, forming the ' foot,' which is in most cases of service in locomotion.

On a very different line of life are the **Arthropods** or jointed-footed animals, including more different kinds than there are in the whole of the rest of the animal kingdom. Here come the scorpions, spiders, and mites (together forming the class of *Arachnids*), the hosts of insects, the centipedes, the millepedes, the great class of crustaceans (like crab and lobster, shrimp and prawn), and several other classes besides. The body is in most cases ringed or segmented, as is very plain in a centipede. The limbs or appendages are many-jointed, hence the name Arthropod (*arthron*, joint, and *pod*, foot). They often serve diverse purposes, and some of them come into the service of the mouth as jaws. From the skin there is produced an external non-living covering, or cuticle, which has to be moulted periodically, as long as the animal continues growing. This shedding of the old husk is very characteristic of Arthropods; and so is the type of nervous system, which consists of a dorsal brain and a chain of nerve-centres along the middle line on the ventral surface.

Starfishes, sand-stars, sea-urchins, sea-cucumbers, and sea-lilies form a well-defined assemblage of classes known as the **Echinoderms** (*echinos*, hedgehog, and *derma*, skin), altogether confined to the sea. They have a great tendency to be five-rayed, and to deposit calcium carbonate in their tissues, often deserving their name ' hedge-hog skinned.' They have a peculiar hydraulic or water-vascular system, which is not seen in other animals.

The **Higher Worms,** such as earthworms and lob-worms and leeches, have a segmented body and are called **Annelids** (*annulus*, a ring). Many of the marine kinds live an active life and have numerous un-jointed bristle-bearing limbs (*parapodia*). These are very well seen in the Nereids that burrow in the sand, or in the beautiful sea-mouse (*Aphrodite*) which has iridescent bristles. The first animals to show limbs are these sea-worms or *Polychaeta*. But many of them live in tubes, made of limestone or of sand-particles glued together, or of other materials, and in these, naturally enough, the limbs are greatly reduced, while the head has often a rich equipment of feeler-like

structures which help in food-wafting, in breathing, in tube-making, in receiving tidings from the outer world, and it may be in other ways. The twisted limestone-tube of *Serpula* is very common on shells and stones. In earthworms and freshwater worms there are no appendages, though they are hinted at by the bristles on the many rings or segments of the body. In leeches, only one kind has anything in the way of bristles; the characteristic feature is the development of a posterior adhesive sucker, a great help to the anterior suctorial mouth.

The **Lower Worms** include many classes: the free-living ribbon-worms or *Nemertines*, unsegmented, ciliated, elastic, with a protrusible, thread-like weapon; the cylindrical threadworms or *Nematodes*, partly free, partly parasitic, with an unsegmented body covered by a firm, resistant cuticle; the parasitic tapeworms or *Cestodes* whose young stages are known as bladderworms; the parasitic flukes or *Trematodes*, such as the liver-fluke that causes liver-rot in sheep; and the simplest worms or *Turbellarians*, flat, ciliated, unsegmented animals, often deserving the name 'living films.' The Turbellarians are almost all free-living—in the sea, in fresh waters, and in damp ground; the flukes are partly external hangers-on and partly internal parasites; the tapeworms are all internal parasites, usually living in the food-canal of their host. In Turbellarians and flukes there is a blind food-canal; in tapeworms the food-canal has disappeared altogether, and the food has to diffuse through the skin. Tapeworms are among the few animals that live on diffusible fluid food, for it is characteristic of animals to require solids. Of course there are many blood-sucking animals, such as leeches and fleas, but it must be remembered that the blood is full of solid corpuscles. It could not seep through the skin as the digested food in the host's food-canal seeps into the tapeworm.

Besides the 'worms' that have been mentioned, which most people would call 'worms,' there are other animals by no means uncommon which may be provisionally slumped together under some title like '**Worm-like**' or '**Vermalia.**' Such are the old-fashioned lamp-shells or *Brachiopods*, which have no relationships with Molluscs; the colonial moss-animals, *Bryozoa* or *Polyzoa*, like the sea-mat, a common marine animal about which Darwin wrote his first scientific paper; and the minute but intricate wheel animalcules or *Rotifers*, some of which are not so large as some of the single-celled animals, though consisting of a thousand cells!

It comes to this: that in the midst of the well-defined classes of backboneless animals there lies, as it were, an ill-defined 'worm' pool, from which streams of life have flowed in various directions. For among 'worms' there may be found affinities with Echinoderms, with Arthropods, with Molluscs, and even with Vertebrates.

Then come the **Stinging Animals** or **Coelentera** — the sea-goose-

berries or comb-bearers, the sea-anemones and reef-corals, the sea-fans and sea-pens, the jellyfishes, the swimming-bells, and the zoöphytes. All but the comb-bearers can sting; all show more or less pronounced radial symmetry like that of a vase; most have tentacles; many form great colonies by budding.

The first animals with multicellular bodies were the **Sponges** or **Porifera,** with skeletons of limestone, or flint (SiO_2), or of spongin, or of spongin and flint combined. All are fixed animals; all depend on in-going and out-going currents of water kept up by the activity of internal lashed cells; all but the members of one family live in the sea.

Lowest of all are the **Unicellular Animals** or **Protozoa.** They do not form a body in the strict sense; they are mostly microscopic and aquatic; they seem to be able in a remarkable way to evade natural death.

As Regards Classification

There are so many different kinds of living creatures that some grouping or arrangement is obviously necessary. But this classification is often very difficult, partly because different kinds of things often fade into one another and do not fit into the rigid pigeon-holes which we make. We may divide the human species (*Homo sapiens*) nowadays into Caucasians, Mongolians, Australians, Negroids, and Negroes; and then we may proceed to divide Caucasians into Europeans, Indians, Semites, and so on; and then we may divide Europeans into Nordics, Mediterraneans, Celts, and so forth. Two points soon become clear, that there are different grades of classification, and that many individuals are very difficult to classify. Caucasians and Mongolians are more different than Europeans and Indians; Nordics and Celts are more different than Welsh and Bretons. So Vertebrates and Molluscs are more different than Birds and Mammals; Carnivores and Rodents are more different than cats and bears; badger and otter are more different than stoat and weasel.

Let us look at it in another way. It is convenient to rank all the tigers together as the *species* tiger, *Felis tigris*. All the members of a **species** show certain, not-trivial, characters with some constancy from generation to generation; these not-trivial characters must be larger than those that distinguish the progeny of a pair; the members of a species should be fertile among themselves, but not readily fertile with members of another species. All the tigers, then, form the species *Felis tigris*.

But there are numerous tiger-like animals, such as lions, jaguars, pumas, and cats, that are so like one another in general characters that we feel bound to rank them in one **genus,** *Felis*. There can be no doubt that they are close blood-relations. Similarly, taking a

slightly wider sweep of the net, all the cat-like animals are included in the **family** *Felidae*, in contrast to civets and mongooses (*Viverridae*) or Hyaenas (*Hyaenidae*). But all the dog-like beasts and all the bear-like beasts are obviously much nearer to the cat-like creatures than to rodents or to whales, and thus arises the need for the **order** Carnivora. But carnivores have much in common with rodents, hoofed animals, insectivores, monkeys, and so on, much more than with birds or with reptiles, and so we establish the **class** of Mammals. Yet again, when we study the mammals, birds, reptiles, amphibians, and fishes, we see that each one of them has a backbone, another supporting-rod in the embryo at least, called the *notochord*, a spinal cord, a brain, two brain-eyes growing out from the brain, a ventral heart, a segmented body (as seen for instance in the vertebrae or separate pieces of the backbone), and (in early stages at least) a set of gill-clefts, i.e. openings from the beginning of the food-canal to the outside world. Thus the classes of mammals, birds, reptiles, amphibians, and fishes are much more closely related to one another than to any big group of backboneless animals. Thus we say that the classes of backboned animals form the **phylum** of *Vertebrata* or *Chordata*. A **phylum** is a group of related classes. The great phyla are: Protozoa, Sponges, Stinging Animals, Flat Worms, Round Worms, Ribbon-worms, Ringed Worms, Echinoderms, Arthropods, Molluscs, Chordates. Perhaps the word *series* (of classes) might be used sometimes instead of *phylum*. The idea of one pigeon-hole within another may be thus represented:

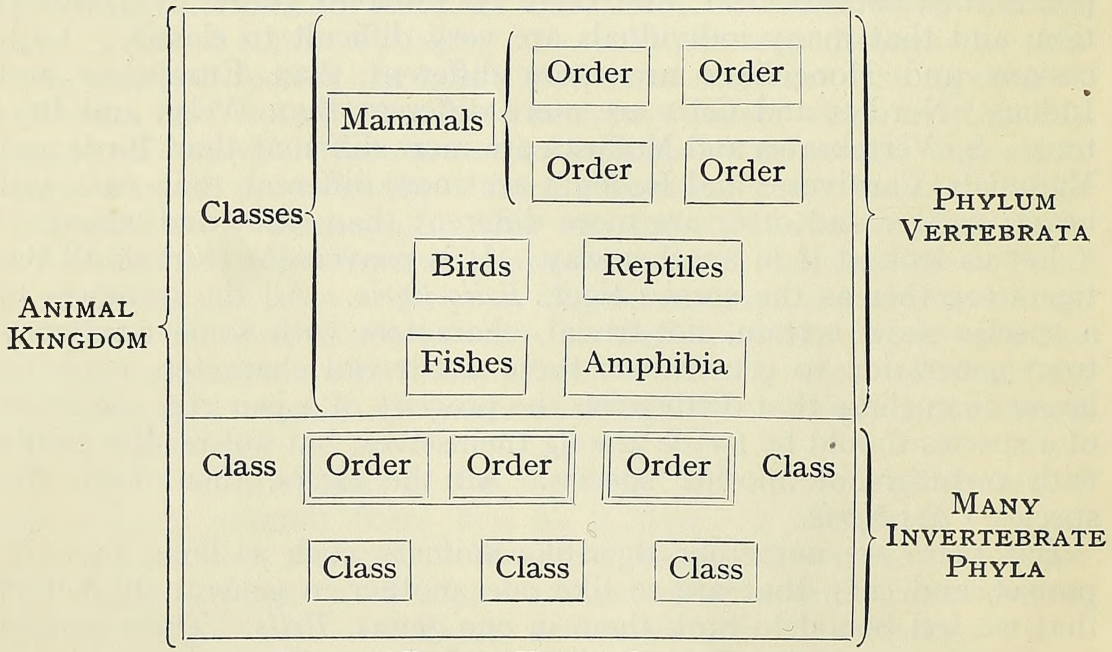


Fig. 2. 'Pigeon-Hole' Classification

A simplified bird's-eye view is given in Fig. 3; the same may be expressed in another way:

Backboned or Vertebrate Animals (Phylum Chordata)

Class, **Mammals**: such as Man, and the orders of Monkeys, Carnivores, Hoofed Mammals, Rodents.

Class, **Birds**: Flying and Running.

Class, **Reptiles**: such as the orders Crocodilians, Tortoises, Lizards, and Snakes.

Class, **Amphibians**: e.g. Frogs, Newts, and burrowing Caecilians.

Class, **Fishes**: Bony, Cartilaginous (' gristly '), and Double-breathers.

Primitive Classes: Round-mouths, Lancelets, Sea-squirts, and Enteropneusts.

Backboneless or Invertebrate Animals

Phylum, **Molluscs**: Classes, e.g. Cuttles, Snails, Bivalves.

Phylum, **Arthropods**: Classes, e.g. Arachnids, Insects, Centipedes, Crustaceans.

Phylum, **Echinoderms**: Classes, e.g. Starfishes, Sand-stars, Sea-urchins, Sea-cucumbers, Sea-lilies.

Phylum, **Annelids**: Classes, e.g. Bristle-bearing Chaetopods, Leeches or Hirudinea.

Several Phyla: **' Worms '** and **Vermalia.**

Phylum, **Coelentera (Stinging Animals)**: Classes, e.g. Comb-bearers or Ctenophores, Sea-anemones and Corals, Jellyfishes, Zoöphytes and Swimming-bells.

Phylum, **Porifera (Sponges)**: Classes, e.g. Calcareous, Flinty, ' Horny.'

Phylum, **Protozoa** or **Unicellular Animals.** Several classes.

Before leaving the difficult question of **Classification,** let us be clear that it simply means grouping similar things together and arranging the groups in pigeon-holes within pigeon-holes. In the directory of any town there is a threefold classification—alphabetical, topographical, and occupational. All the A's are brought together, though they have often nothing in common except that they are citizens and have their family name beginning with the same letter. All the householders in one street are brought together, though they are as different as different could be. All the butchers and the bakers and the candlestick-makers and so on are brought together in groups, the common feature in each case being sameness of occupation. Now

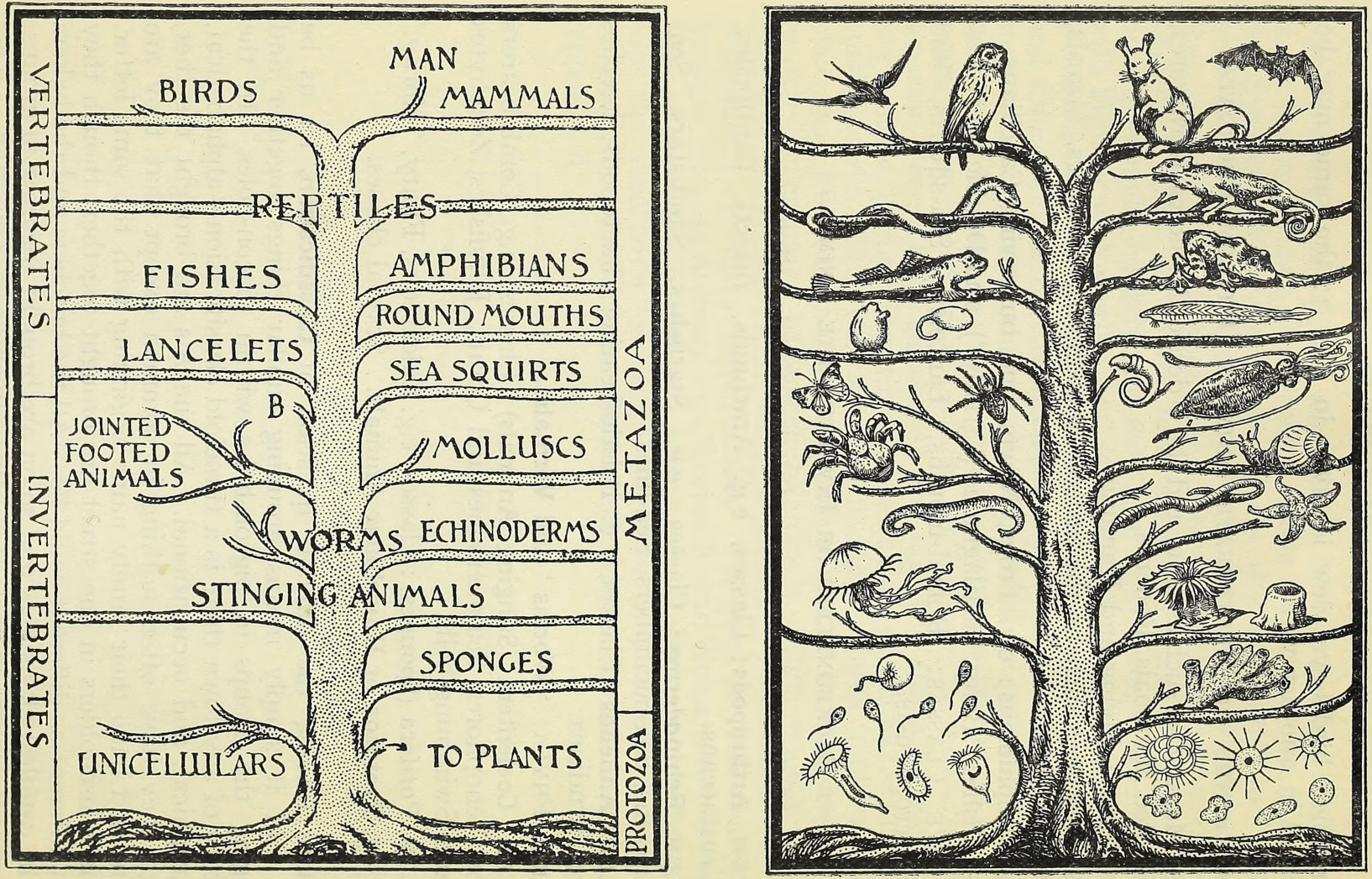


FIG. 3. CLASSIFICATION OF ANIMALS, EXPRESSED AS A GENEALOGICAL TREE

B, *Balanoglossus* (*Enteropneusta*), an important connecting-link between Vertebrates and Invertebrates. See INDEX.

these are classifications of convenience, but a scientific classification should be more than that. It should have more *meaning*; it should tell us that the members in each group have big things in common, are indeed blood-relations.

It used to be the custom to classify birds according to their habit, as climbers (*Scansores*), runners (*Cursores*), swimmers (*Natatores*), scratchers (*Rasores*), and so on; and this is a very interesting classification. But its defect is that birds that are not nearly related to

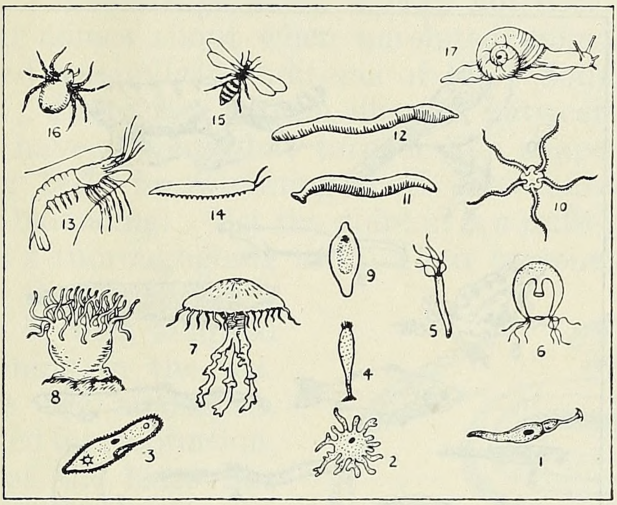


FIG. 4. DIAGRAM OF TYPES OF INVERTEBRATE ANIMALS

1. Gregarine; 2. Amoeba; 3. Paramecium (Protozoa); 4. Simple Sponge (Porifera); 5. Hydra; 6. Medusoid; 7. Medusa; 8. Sea-anemone (Coelentera); 9. Liver-fluke (Platyhelminthes); 10. Brittle-star (Echinoderms); 11. Leech; 12. Earthworm (Annelids); 13. Prawn (Crustaceans); 14. Peripatus; 15. Wasp (Insects); 16. Garden Spider (Arachnids); 17. Snail (Gastropod Molluscs).

one another often have similar habits. Thus swifts and swallows have somewhat similar habits, but they are not nearly related to one another. Swallows are perching birds (*Passeres*); swifts come near goatsuckers.

What then is the test of being nearly related? The test is to be found in deep-seated resemblances of structure and development. Blood-relationship is revealed in deep samenesses of bodily architecture. Thus bats are not birds, for the resemblances are quite superficial.

HOMOLOGOUS AND ANALOGOUS.—When two parts are the same in their fundamental structure and mode of development they are said to be **homologous**—a very useful word. Thus the arm of a man, the fore-part of the wing of a bat, the fore-leg of a horse, the wing of a bird, and the flipper of a turtle, and so forth, are all **homologous.** For

they are all fore-limbs, with the same chief bones, muscles, nerves, and blood-vessels, and they all develop as the fore-limbs of back-boned animals do, like little buds on the anterior region of the body of the embryo.

When two parts have the same function or use they are said to be **analogous**—another useful word. Thus lungs and gills are both breathing organs, the former for use in dealing with dry air, the latter for dealing with air dissolved in the water. But a lung is more or

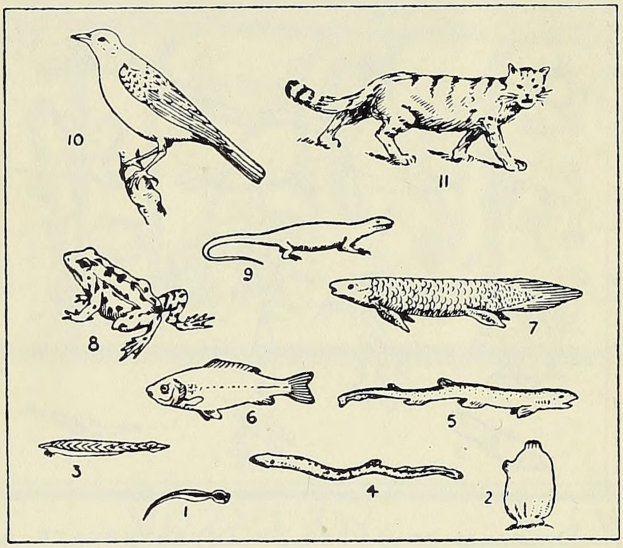


FIG. 5. DIAGRAM OF TYPES OF VERTEBRATE ANIMALS

1. Tadpole-tunicate; 2. Ascidian; 3. Lancelet; 4. Lamprey (Cyclostomes); 5. Dogfish (Elasmobranchs); 6. Carp (Teleosts); 7. Mud-fish (Dipnoi); 8. Frog (Amphibians); 9. Lizard (Reptiles); 10. Bird; 11. Wild Cat (Mammals).

less of a spongy bag, containing air and possessing blood-vessels on its inside walls, whereas a gill is like a feather with a large surface on which the blood-vessels are spread out. *Lungs and gills are analogous but not homologous.* Similarly the wings of a bird and the wings of a butterfly are analogous, since both are organs of true flight, but they are not in any way homologous, since the wings of a bird are transformed fore-limbs, whereas the wings of butterflies are flattened sacs that grow out from the upper parts of the sides of the anterior body (or *thorax*) of the insect. It may be, however, that two structures are both homologous *and* analogous. Thus the wings of a bird and the fore-part of the wings of a bat are both fore-limbs, and they are both organs of true flight. These distinctions were first made clear by the great anatomist Sir Richard Owen, and they are not *wordy* distinctions at all; they make for clearness of thinking. For example:

(1) The wing of a bird and the arm of man: homologous but not analogous.

(2) The wing of a bird and the wing of a butterfly: analogous but not homologous.

(3) The wing of a bird and the wing of a bat (in its front part): homologous *and* analogous.

There is another kind of resemblance which has often led to mistakes in classification. It is a superficial, though not necessarily external, resemblance that comes about when unrelated animals are similarly suited or adapted to similar conditions of life. Some examples will make this clear. There is a certain likeness between a dolphin and a shark. Both have a somewhat torpedo-like shape of body; both use the posterior body in swimming; both have anterior flipper-like limbs, suited for balancing. Yet the dolphin is a milk-giving mammal, and the shark is a thoroughgoing fish. Their samenesses are mainly due to the fact that both kinds of animals have become adapted to active swimming in the sea. Lungs and gills are analogous, both are well suited for respiration, but they are not the least like one another.

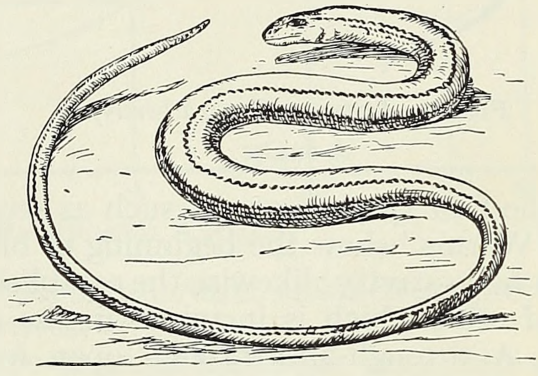


Fig. 6. Slow-worm (*Anguis fragilis*)
A limbless lizard.

A slow-worm is from a distance like a snake, particularly like a burrowing snake; but the two kinds of animals are very unlike one another internally. Both are reptiles, but the slow-worm is a limbless lizard, while snakes belong to a separate class. Why, then, are they superficially like one another? Because they are similarly adapted to similar conditions of life, creeping through narrow passages or burrowing in the ground. Beside the slow-worm and the burrowing snake might be placed the blindworm, a limbless subterranean amphibian (*Caecilia*); the three creatures illustrate **convergence,** but they are far from being closely related.

Centipedes and millepedes, with their multitudinous legs and elongated body, are in some measure alike, especially to the uncritical eye, but, as will be seen later on, they are very different. The two classes of centipedes and millepedes, which used to be grouped together as *Myriapods*, are, in fact, not nearly related to one another. The two kinds of creatures are similarly adapted to creeping through crevices. They illustrate **convergence,** or what is sometimes called homoplasty: they are similarly fitted for similar habits and surroundings.

BEGINNINGS.—It is very interesting to ask when certain structures of importance first made their appearance, and a few illustrations, to be added to later on, may be given at this stage.

Protozoa show the beginnings of cell-structure, of the great activities of life, of different kinds of multiplying, of sex. Sponges were the first animals to be successful in having a multicellular body, and the tax on having a body is natural death. Sponges also show the beginnings of tissues.

Stinging Animals show the first true mouth and food-canal; likewise

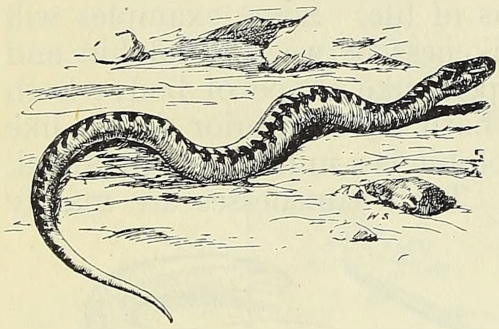


FIG. 7. ADDER (*Vipera berus*)
A snake.

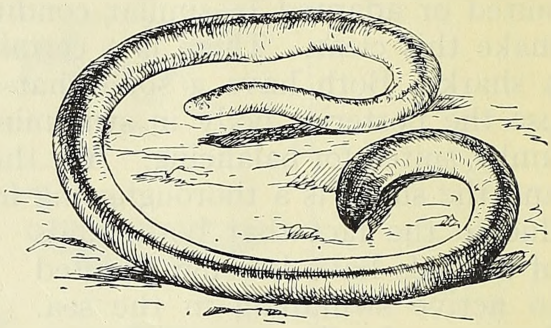


FIG. 8. BLINDWORM (*Caecilia*)
A limbless subterranean amphibian.

the first special organs, such as sense-organs and reproductive organs. 'Worms' show the beginning of bilateral symmetry, head-brains, and a body-cavity; likewise the establishment of the *mesoderm* or mid-layer of cells, which is incipient in the comb-bearing Coelentera.

A through-and-through open food-canal, with a vent or *anus* as well as a mouth, is first seen in Threadworms or Nematodes. These are also the first animals to show 'moulting.'

Blood is first seen in Ribbon-worms or Nemertines, and some of them have *haemoglobin*. This is the red blood pigment characteristic of backboned animals, and is very important because of its strong chemical affinity for oxygen, which it readily captures from the water or air.

The first paired limbs are the bristle-bearing, unjointed appendages (parapodia) of many marine Annelids.

The first jointed legs are seen in Arthropods, such as the ancient extinct *Trilobites*, or the modern Crustaceans, Centipedes, Insects, Scorpions, and Spiders.

The head begins to come into its own for the first time in some of the bristle-footed marine worms, where it is a well-defined region and bears feelers of various kinds and eyes, besides, it may be, hard jaw-like structures in the mouth and a protrusible proboscis. A very good example is the head of the worm *Nereis*, a marine animal some-

times as long as one's arm. The first *true* jaws among Invertebrates are seen in jointed-footed animals like Crustaceans and Insects, meaning by 'true jaws' that they are genuine appendages or limbs brought into the service of the mouth.

The characteristic features of backboned animals, namely the dorsal nervous system, the dorsal supporting-rod called the notochord, the ventral heart, the brain-eyes, and the gill-slits, make their appearance among the primitive Chordates—the Enteropneusts, the Sea-squirts, the Lancelets, and the Round-mouths. But only in the last are all the five seen together.

The first Chordate animals to have a skull, a brain, two brain-eyes,

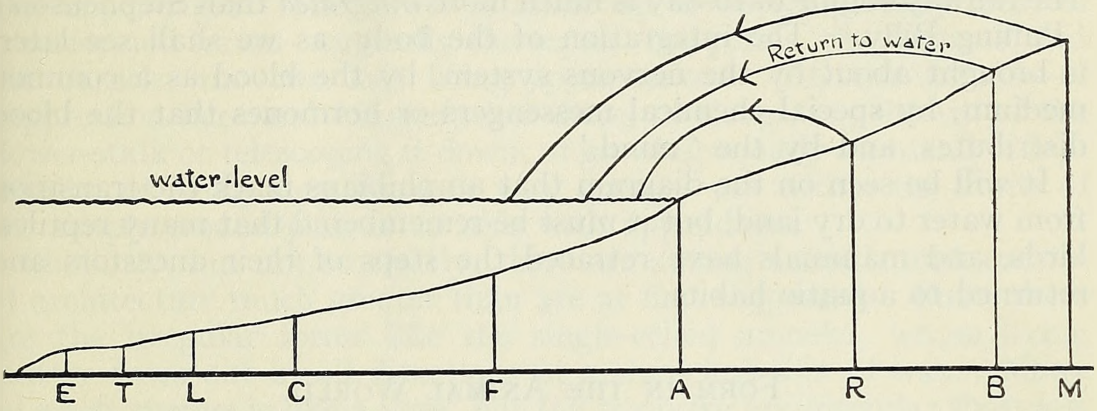


FIG. 9. ASCENT OF BACKBONED ANIMALS

and gills beside the gill-slits are the Round-mouths, of which lampreys and hags are the living representatives.

Fishes are the first animals to have bones, a backbone, jaws, paired limbs, scales, and bony teeth.

Amphibians gained fingers and toes, true ventral lungs, breathing nostrils opening posteriorly into the mouth, a three-chambered heart, vocal cords, and a movable tongue.

The first four-chambered heart occurs in Crocodilians, and Reptiles are the first animals to show two birth-robes (membranes round the embryo), called the *amnion* and the *allantois*.

Birds and Mammals are the only warm-blooded animals; they are the first Vertebrates to have only pure blood driven from the heart to the body, and the first animals to have really large brains. The higher mammals show a great advance in the front region of the fore-brain, and they have a close union between the offspring and the mother before birth.

The ascent of Backboned Animals may be shown in the diagram on this page, where the perpendiculars marked E, T, L, C, F, A, R, B, and M stand for Enteropneusts, Tunicates, Lancelets, Cyclostomes or Round-mouths, Fishes, Amphibians, Reptiles, Birds, and Mammals.

What do we mean by the different heights of these perpendiculars? What do we mean when we say that one animal is *higher* than another? The answer to this important question is that there are two standards by which we measure the position of an animal in the scale of being. The first standard is complexity or intricacy of structure, having many different parts and much division of labour. The technical word for this is **differentiation**—a word that cannot be dispensed with. The railway engine of to-day is much more *differentiated* than Stephenson's 'Puffing Billy.' The second standard is the degree in which the body is controlled or harmonized, or bound into one. The technical word for this is **integration**—another word that we cannot do without. The railway engine of to-day is much more *integrated* than Stephenson's 'Puffing Billy.' The integration of the body, as we shall see later, is brought about by the nervous system, by the blood as a common medium, by special chemical messengers or hormones that the blood distributes, and by the 'mind.'

It will be seen on the diagram that amphibians mark the transition from water to dry land, but it must be remembered that many reptiles, birds, and mammals have retraced the steps of their ancestors and returned to aquatic habits.

Form in the Animal World

When we visit a natural history museum with an unprejudiced mind we get an impression of bewildering variety of form. The long-necked giraffe and the short-necked whale are in the same class of mammals; the snake and tortoise are both reptiles; the compact toad and the serpentine blindworm are included among amphibians; the spherical globe-fish and the eel are fellow-fishes; the butterfly and the beetle are equally insects; the lobster and the rock-barnacle are both crustaceans; the sea-urchin and the starfish are beside one another among echinoderms; and so the contrasts continue till we see plainly that shape cannot be regarded as characteristic of affinity except within a narrow radius of relationship. In one class there may be all sorts of shapes and sizes. It looks as if shape was somewhat or altogether secondary and superficial, adapted to the diversity of habits and surroundings. Yet this is not the whole story.

QUAINT SHAPES.—Besides the great difference of shape that there often is between animals not very distantly related, such as skate and shark, flying phalanger and marsupial mole, slow-worm in the earth and chamaeleon on the tree, blue-bottle and sheep-ked, another impressive fact is the occurrence of many quaint or bizarre forms. It is difficult to look at a bat without smiling, and an elephant is almost incredible! Among lizards the horned toad of Arizona and the

moloch of Australia are like artists' grotesques, and the chamaeleon is a grinning gargoyle. A puffin is a quaint bird, and the wingless kiwi of New Zealand is like a contradiction in terms. A box-fish is an oddity, and the graceful movements of the sea-horses, with their prehensile tails twisted round the seaweed, keep one merry for days. Another queer fish is the fishing frog. But there is no point in continuing the list, for it will be granted by all that the shape-limits of animals are very wide.

TYPES OF ARCHITECTURE.—Flowering plants seem to the young botanist to be incalculably diverse, but, as the poet Goethe was one of the first to discern, they are all referable to one ground-plan—an axis and appendages. The flower is made up of *whorls* (usually four) of transformed leaves—typically the sepals, the petals, the stamens, and the carpels, the two last being spore-makers. All the details—of suppression here and exaggeration there, of elongating the tip of the flower-stalk or telescoping it down, of growing equally all round or lopsidedly, of being very floral or very grassy—are within the limits of the simple ground-plan of an axis with appendages.

Similarly, but not so clearly, there are among animals uniformities of architecture much greater than are at first suggested. First, there are the irregular forms like the single-celled amoeba, whose living matter flows out in all directions in a shapeless sort of way. Many an adult sponge is like a vase, but the majority are irregular shapeless masses. Secondly, there are spheres, like many of the beautiful pinhead-like *Radiolarians* of the open sea, or the *Volvox* of our ponds —a green ball of a thousand to ten thousand cells. This kind of architecture is suited for drifting or swimming freely in the water. A secondary spheroidal form appears in globe-fishes, some of which are able to inflate their body like a football, and move about, upside down, in a leisurely way on the surface of tropical seas. Another spherical type, secondary rather than primary, is the common sea-urchin, whose shape and spines suggest a rolled-up hedgehog.

RADIAL AND BILATERAL SYMMETRY.—The third type of architecture is radial, where the body is thimble-like or saucer-like, having no right or left side, being in fact the same all round. Sea-anemones and other polyps illustrate radial symmetry among sedentary types, while jellyfishes and medusoids are radial and free-swimming. It is a kind of shape well suited for an easy-going kind of life, moving gently in the uniformity of the open sea or waiting on a rock for food to come within reach of the tentacles.

The fourth type of animal architecture is bilateral, which practically began with worms and was consummated in man. It implies the possession of right and left sides, also a head and a tail end. It means that the body can be divided along one plane (and only one) into two mirroring

halves, whereas a jellyfish, like a round cake, can be divided with equal fairness by an indefinite number of vertical cuts. The acquisition of bilateral symmetry was the beginning of a more vigorous mode of life, for it implies the power of rapid movement in one direction. This was primarily adapted to pursuing booty, avoiding enemies, and chasing mates. It was associated with the appearance—in individual development and in the racial evolution—of a brain in the head region. In a deep sense, the acquisition of bilateral symmetry was the beginning of our knowing our right hand from our left.

The fundamental shape of the body depends on the physics of growth, which is, of course, inseparable from the chemical nature of the living stones and mortar in each particular organism. This takes us back to the nature and disposition of the materials in the egg-cell, and to the way in which the egg-cell divides.

The details of shape-taking also depend on biophysical and biochemical laws, but they are influenced by the activities of the creature and by its surroundings. There is an Indian Ocean hermit-crab that lives in pieces of bamboo-stem and retains the early bilateral symmetry which ordinary hermit-crabs lose when they tuck themselves into a borrowed spiral shell.

Many details of shape are simply exuberances of orderly growth within the limits allowed by the struggle for existence, and require no utilitarian justification. Other details have become particularly well adapted to particular exigencies of habit and habitat, and have not been successfully interpreted except on Darwinian lines—in terms of Nature's sifting or natural selection. But while a particular environment may select *automatically* a particular shape, a particular shape may select *deliberately* a particular environment!

CHAPTER III

THE SIMPLEST ANIMALS OR PROTOZOA. CELLS

In the Beginning—How the earth became suitable for living creatures—Origin of living creatures upon the earth—Mostly very minute—Very simple—Three great divisions—Habitats—Ways of multiplying—Beginnings—Exempt from natural death—General characters—Important Rhizopods—Chalk—Symbiosis—Important Infusorians—Important Sporozoa—Protozoa and disease—Protozoa and the web of life—Cells: What is meant by a cell—The cell-theory—The structure of the cell—The life of the cell—Different kinds of cells—Cell-division.

IN THE BEGINNING.—The astronomers tell us that our whole solar system—the central sun, the inner planets (Mercury and Venus), the Earth and its Moon, and the outer planets (Mars, Jupiter, Saturn, Uranus, Neptune, Pluto)—was once represented by an enormous **nebula**, i.e. a whirling mass of minute particles. The centre of this vast incandescent cloud became the sun, from which were split off the planets, including the earth. These matters are dealt with in books on astronomy; here we must simply take for granted that our earth arose from a spinning nebula. It may be noted, however, that there are great spirally twisted nebulae to be seen in the sky to-day which look as if they were forming more solar systems even now!

Before we go further, however, we must notice the question: What came before the nebula? The answer must be that we do not know. But even if we did know, and could say that before the solar nebula there was a state of things called *x*, then the same kind of question would arise: What came before *x*? Therefore we must be content to say that while we can think clearly about *a* beginning, such as the cooling earth, we cannot picture *the* beginning. This takes us *beyond Science*, and perhaps the best answer is the old religious one: '*In the beginning God created the heaven and the earth.*'

The second difficult thing to be said is this. We see a beautiful flowering plant spring from a little brown seed that we put into the ground; we see a lively chicken struggle out of an egg which three weeks before would have shown us not the least hint of what was going to happen; we see an infant growing into a clever child; and we know that the seed, the egg, the infant had in it the power of becoming what it became, provided always that it got food and air and warmth and other necessaries. It looks as if we must think in the same way about the whirling nebula. It looks as if it must have had in it the

promise and the power of our fair earth and all that in it is. If so, then there must have been in the nebula more than would have met the eye, had there been any observer there to see. There must have been in the nebula, in some way that we do not understand, the potentiality of giving rise to living creatures, even to living creatures with minds and wills of their own. Now, we cannot imagine mind, e.g. thinking and feeling, being produced by matter of itself. That would be a kind of jugglery. So it seems wisest to suppose that in the original nebula there were hidden powers corresponding, afar off, to that kind of activity that we call life, and likewise to our power of thinking, or to the simple animal's power of feeling. This brings us to the old conclusion: '*In the Beginning was Mind.*' This is a scientific book, but we do not think that there will be found in it anything that is not in tune with these two conclusions which go beyond Science: '*In the Beginning God created the heaven and the earth*'; '*In the Beginning was Mind.*'

HOW THE EARTH BECAME SUITABLE FOR LIVING CREATURES.—For an unthinkably long time—for millions of years—the earth was very hot, and there was not the faintest possibility of its being tenanted by living creatures. The surface was smoking and cindery; the only streams were of lava; the atmosphere was unbreathable—with much carbon dioxide and nitrogen, with some water-vapour, but with only a trace of the oxygen which all living creatures require. No sun by day, nor moon by night, nor any stars, but a thick curtain of cloud over all the earth! It was not a very promising stage, the surface of the cooling earth, perhaps 800 million years ago.

What were the great changes that made the earth suitable to be first a cradle, and then a home of life? First there was the cooling of the crust, which consisted mainly of the rather lighter materials—the heavier, more metallic rocks being at the core. Second, from the dusty atmosphere there was a sinking of water-vapour into the dusty crust, till by and by in hollows among the dunes there must have been the first gleam of water. Pools and lakelets grew into lakes and seas, and there are some authorities who think that there was once a universal ocean.

Third, there was a buckling of the floor of the sea, as the cooling earth became smaller; and this was the beginning of the establishment of continents. The thick atmosphere, which may have served as a sheltering screen and blanket in early ages, became clearer, and the sun shone through. There began to be a porous soil, and a very important circulation of water. For we cannot think of the earth as we know it without its water-circulation. The water-vapour in the cloud is changed on the cool rock into drops of water; these seep through porous surfaces and sink through the hidden ways of crevices

into runlets, which are added up into streams, which flow to the sea. With the help of carbon dioxide from the atmosphere, the water is better able to filch mineral matter from the rocks, and thus the sea becomes salt. The dissolving of the materials from the rocks makes them more liable to break down or 'weather,' and this results in small particles which the streamlets carry to the valleys, there to form soil. In the heat of the day the water-vapour is raised as mist from the sea; clouds are once more formed and shepherded by the wind across the sky; and this cycle, which keeps everything going, continues ceaselessly from age to age. It would be difficult to make too much of the importance of water in the history of the earth—it dissolves matter and carries it in solution; it changes easily from form to form; it enters readily into union with other substances; it regulates the temperature; it keeps the composition of the sea more or less constant; it makes channels in the earth. In living matter itself there is usually at least seventy per cent of water. What the circulation of the blood is in our body, such is the circulation of water in and on the earth.

Thus, to the question: *How did the earth become fit to be a home of life?* we should answer: The crust cooled, a clearer atmosphere was formed, the sun shone through, water-vapour became water in hollows of the earth, there was a growing of seas and an establishment of continents, there began to be a circulation of water and what water could carry. There were yet other 'preparations,' if we dare use this word, but those that we have mentioned are the most important. It is clear that many changes working together made the earth a very different place from what it was when it first took shape out of the fire-mist.

ORIGIN OF LIVING CREATURES UPON THE EARTH.—This is such a difficult question, that many wise people would simply give the answer in the Bible:

'And God said, Let the earth bring forth grass, the herb yielding seed, and the fruit tree yielding fruit after his kind, whose seed is in itself, upon the earth: and it was so.'

'And God said, Let the waters bring forth abundantly the moving creature that hath life, and fowl that may fly above the earth in the open firmament of heaven.'

'And God said, Let the earth bring forth the living creature after his kind, cattle, and creeping thing, and beast of the earth after his kind: and it was so.'

Now this is part of an ancient religious poem, and it expresses what many of us believe to be a religious truth, that the Power of God has been behind everything that has happened since the beginning.

Unless we take the poem in a rather wooden way, and picture, for instance, a sudden peopling of earth and sea, there is no reason why we should not hold to its religious truth, and yet go on to puzzle over *the particular way* in which living creatures might have begun to be upon the earth. Science tries to describe; Religion seeks to interpret. They speak different languages.

Some people, who are also wise, give a second answer, that we simply do not know how living creatures began. This is true: we do not know. Perhaps we are not asking the question in the right way. This is the cautious scientific answer, but the curious thing is that the question will not be put to sleep. We know that we can give no certain answer, and yet in the back of our mind the question stirs: No doubt by the will of God, but *in what particular way* can living creatures have made their appearance on the earth? Can we make no scientific picture?

A third answer has been given by several great discoverers, notably Lord Kelvin and Helmholtz, who suggested that very simple forms of life may have reached the earth well wrapped up in the crevices of a meteorite, like one of those 'falling stars' we often see. The earth has received an immense number of these contributions 'from elsewhere,' and we know that some forms of life, such as seeds, can survive extremes of temperature, both high and low. On the whole, however, in spite of the great men who have made the suggestion, the probabilities are against the possibility of germs of life taking a long journey through space. And even if the suggestion be accepted, it simply shifts the problem of the origin of living creatures from the earth to somewhere else.

The fourth answer is that simple living creatures may have arisen from not-living materials upon the earth. The modern chemist does wonders in the way of building up complex things out of simple things. By artificial means he brings about the combination of simple substances so that they form intricate compounds like sugar, indigo, alcohol, and rubber. This building-up of simple chemical substances so that they form complicated compounds is called **synthesis,** and what can be done in the chemical laboratory also occurs in living creatures. The most important example is the building-up that goes on in every green leaf in the sunlight. With the help of the **energy** (i.e. power of doing work) of the red-orange-yellow rays of the sunlight, the leaf is able to use carbon dioxide and water so as to build up sugar and starch and even more complex carbon-compounds. This is the most important process in the whole world, for it means that green plants are manufacturing food, not only for themselves, but for plant-eating animals as well. We must have a name for the most important process in the world, and the name is **photosynthesis,**

which means using light to build complex carbon-compounds out of simple substances.

Before the twentieth century no one thought that this building-up with the help of light could be effected by anything but a green living creature, usually a green plant. But Professor Baly of Liverpool and his fellow-workers have been able to use light (of various kinds, including sunlight) to build up sugars and other complicated substances. Starting with nothing but carbon dioxide (CO_2) and water (H_2O), on which the light was made to play for a long time, the experimenters were able to make sugar; and by adding a salt (a nitrite) related to saltpetre they were able to make nitrogenous carbon-compounds not very far away from those substances (proteins) which form part of the living matter of all living creatures.

If this building-up can be brought about artificially, it may also have been effected in not-living Nature. With the help of the sunlight, such simple materials as carbon dioxide, water, and nitrites might be built up into the raw materials of living matter, and some combination of these raw materials might result in a very simple kind of living creature. It is convenient to use the word **protoplasm** for genuinely living matter, what Huxley called ' the physical basis of life.' It is convenient to use the word **organism** for any living creature, whether plant or animal, or between the two.

So the fourth answer to our difficult question is that protoplasm and organisms may have arisen by natural processes from not-living matter. When experimenters have tried to make simple living creatures out of not-living materials, they have always failed. So far as we know, there is no **spontaneous generation** (the origin of the living from the not-living) going on to-day; there is certainly no hint of it in careful experiments. Therefore men of science say, *Omne vivum e vivo:* All life springs from life. Every living creature that we know comes from a parent or from parents like itself. But it does not follow that this has been always true. It may have been that in the early days of the earth some simple living creatures arose from not-living materials. And we should not be too sure that something of the sort *cannot* take place in natural conditions to-day, for some of the simplest living creatures are so minute that if they did appear out of the not-living, they would not be readily noticed.

To sum up, the scientific answers to the question how living creatures began to be upon the earth are: (*a*) that we do not know, (*b*) that simple beginnings may possibly (but improbably) have come in a meteorite or along with interplanetary dust from elsewhere, and (*c*) that very simple organisms may possibly have arisen by natural processes from material that was not-living. But however they arose, very simple organisms are common to-day, and we must pass on to their study.

Protozoa

MOSTLY VERY MINUTE.—The simplest animals are mostly invisible to the naked eye; and some may be called extremely invisible, since they cannot be seen without a high-power microscope. Besides being very minute, many of them are almost transparent and therefore very inconspicuous as they dart across the drop of water that we are examining under the microscope. The minute animals called *Trypanosomes* that cause sleeping sickness in man, when the tsetse fly introduces them into his blood, are often very abundant, and yet it takes some training of the eye before they can be detected in a blood film examined by very powerful lenses.

If the water in which cut flowers have been standing be held against the light, we see minute bodies darting about. Most of these are very simple animals, called *Infusorians*, that were lurking in a quiescent state in the crevices of the flower-stalks, or perhaps in the water itself. One of the largest of these is the slipper animalcule (*Paramecium*), which is about a hundredth of an inch in length. There are many Protozoa larger than this; thus most of the chalk-forming animals or *Foraminifera* are easily seen with the naked eye. But we may safely say that a Protozoön is considered large if it is the size of a pin's head.

VERY SIMPLE.—But it is not merely minuteness of *size* that distinguishes the Protozoa: they show great simplicity of *structure*. They have no organs like higher animals, and it is usual to speak of them as 'single cells.' It must be understood, however, that many of them show considerable intricacy on a minute scale, having, for instance, a mouth, a set of locomotor lashes, a kernel or nucleus, pulsating vacuoles, and something in the way of skeleton. They are much more intricate than ordinary single cells, such as white blood corpuscles, taken from the body of a higher animal; and it must be understood that they are complete living creatures. Perhaps it would be best to say that the Protozoa are very minute animals that have not (except in a few cases) gone in for cell-making. Those few that form loose colonies of cells, point the way to the multicellular animals (or **Metazoa**), which include everything from sponges to man.

THREE GREAT DIVISIONS.—Some of the Protozoa move about very rapidly by means of living lashes (*cilia* or *flagella*); and these are called **Infusorians**. Among them are the slipper animalcules (*Paramecium*), the sleeping sickness animals (*Trypanosomes*), and the night-light (*Noctiluca*) of all the seven seas, which makes the oars sparkle with 'phosphorescence' in the short summer darkness.

A second subdivision of the Protozoa includes the sluggish parasites (**Sporozoa**) which infest all sorts of animals. One of the worst of them

is the malarial organism (*Plasmodium*) which is introduced into man by the bite of an infected mosquito. It is very unusual to open an earthworm without seeing conspicuous spots on the reproductive organs, and these are large Sporozoa (*Monocystis*) or clusters of them. If a smear is made with a drop of water, it is easy to see under the microscope that the Monocystis multiplies by forming a large number of units or *spores*. This way of multiplying is characteristic, hence the name *Sporozoa*.

There is a third subdivision of Protozoa, including forms neither very active nor very sluggish, but on a middle way between these extremes. Most of them have outflowing processes of their living matter in the form of threads or blunt lobes, which are used in locomotion and also in capturing food. To Protozoa of this type the name **Rhizopod** is given, and here are included the *Amoebae*, the beautiful chalk-forming *Foraminifera*, the not less beautiful *Radiolarians* which mostly have shells of flint, the elegant sun animalcules, and many more besides.

It is plain that the Infusorians with their living lashes are constitutionally very active; the parasitic Sporozoa are very sluggish, with no locomotor processes unless it be in young stages; the naked Rhizopods with their outflowing threads or lobes are between the two. This is a kind of forking of the ways that seems to have occurred often in the advance of life: some forms diverge on a line of greatly increased activity; some of their relatives sink into easy-going, sluggish habits; others, again, continue along the middle path, the *via media* of compromise. There are always these three possibilities.

If the grouping of the Protozoa is a natural one, it should be possible to apply it to a classification of the cells that build up a many-celled animal. And that can be done. (1) The cells lining our windpipe are ciliated and very active, though they do not move about. They and other ciliated cells may be compared to Infusorians. The cells that keep the currents of water going inside a sponge are flagellate cells, very like some of the Infusorians called *Monads*. A male fertilizing cell or sperm-cell usually moves about by means of a flagellum and is thus helped to find the egg-cell. (2) A cell laden with fat is a sluggish cell that might be compared to a Sporozoön. So might a cell that goes in for forming gristle or cartilage, or an unexercised muscle-cell that has become degenerate. A ripe ovum or egg-cell, rich in stored reserve materials, and encased in a firm envelope, may also be likened to a Sporozoön, and the justness of the comparison is not lessened by the fact that the young egg-cell is often amoeboid, as is well seen in the freshwater *Hydra*. For the young Sporozoön is often amoeboid in its young stages, as is well illustrated in the life-history of the Sporozoön that causes malaria. (3) The

colourless cells of the blood (the white corpuscles or **leucocytes**) are like small amoebae. They move by protruding blunt processes and with these they are also able to engulf particles. In backboned animals there is a kind of white blood corpuscle that passes through the walls of the blood-vessels and migrates into the tissues, where it may engulf and digest an intruding microbe. These wandering amoeboid cells are called **phagocytes,** and they are very important in several ways. They occur in almost all kinds of animals from sponges to man, even in animals which have no blood. The threadworms (*Nematodes*) and the lancelets (*Amphioxus*) are almost the only animals that have no wandering phagocytes. It will be clearly understood that though they are amoeboid they are not amoebae; they are cells belonging to the body and often form a bodyguard against intruding microbes; they may be particular kinds of white blood corpuscles, as we have said, or they may be apart from blood altogether. Let us sum up their uses:

Phagocytes

(1) May engulf and digest bacteria or other intruding microbes, as in man.

(2) May form a barrier around intruding bacteria, shutting them in.

(3) May transport food-particles from one part of the body to another, as in sponges.

(4) May carry away other kinds of particles, e.g. pigment from a hair.

(5) May act as sappers and miners when the body is undergoing some great change (*metamorphosis*), as when a maggot becomes a fly.

(6) May help in the regrowing of a lost part or in the mending of a wound, as in earthworms.

The word phagocyte means 'devouring cell' (*phago,* devour; *cyte,* cell), and the allusion is to the way in which certain kinds of phagocytes are able to devour intruding bacteria. This life-saving process is called **phagocytosis** and was first brought clearly to light by the Russian naturalist Metchnikov. At present, however, we are simply concerned with the fact that the phagocytes of our body, or of an animal's body, are like those Protozoan animals that are called Rhizopods, e.g. the common amoebae. To sum up:

Chief Groups of Protozoa

Infusorians	.	comparable to ciliated cells lining the windpipe or to sperm-cells.
Rhizopods	.	comparable to our white blood corpuscles or to some young ova.
Sporozoa	.	comparable to fat-cells or to ripe ova.

HABITATS.—There are many Protozoa in fresh waters, e.g. slipper animalcules dashing about, the bell animalcules (*Vorticella*) attached by contractile stalks to water-weed, the amoebae gliding along mysteriously on the mud, some sun animalcules drifting in well-lighted, quiet corners of a pool. Very interesting is the rotating green ball *Volvox*, as big as a pin's head, sometimes found in forsaken canals and the like; it is a colony of a thousand to ten thousand cells (there are different kinds, like *Volvox aureus* and *Volvox globator*), and it illustrates how some of the Protozoa do their best, as it were, to cross the Rubicon into the kingdom of the multicellulars, or Metazoa. Volvox is often claimed by the botanists, for it has the green pigment *chlorophyll*, and feeds mainly as a plant. It is very difficult to settle these questions.

Some of the Protozoa live in damp earth, such as *Amoeba terricola*; but we do not know much about those in this habitat. A great many, as we have said, live as unpaying boarders inside other animals; and it is interesting, indeed so unusual that it is startling, to find one of the relatives of the sleeping sickness animals (*Trypanosoma*) thriving inside the milky tubes of a kind of spurge or *Euphorbia*. There are other strange habitats, such as the human mouth, where some amoebae lurk very persistently, and do great harm among the teeth and in the gums; but, after all, the huge majority of the Protozoa are at home in the sea. Most of the Foraminifera, whose shells formed long ago, in slowly accumulating deposits, the chalk cliffs of Dover, glide about on sea-weeds and rocks in shallow waters; but the *Globigerina* drift in the open ocean, and, as they are killed by sudden changes of temperature or other vicissitudes, sink slowly in a ceaseless rain to the darkness of the great abysses where they form Globigerinid ooze. Also belonging for the most part to the open sea—the **pelagic haunt**—are the Radiolarians, which have shells made of flint, or of a transparent protein material called acanthin. From the coastal shallows to the open sea there are abundant Infusorians, some of which, probably keeping up a primeval tradition, have chlorophyll, and are able to feed like green plants.

WAYS OF MULTIPLYING.—Protozoa multiply by dividing into two or more units; and this multiplication can go on so quickly, often once every twenty-four hours, that vast populations soon arise. In most cases this **fission** or multiplication by division—which seems a queer thing in arithmetic — is interrupted every now and then by **conjugation,** when two individuals become temporarily or permanently one. In the latter there is obviously reduction in number, but Professor Woodruff of Yale University has been able to keep a lineage of Paramecium alive for ten years without there being anything but this asexual division of one into two. When the Protozoön forms

many minute units at once, we speak of multiplication by **spore-formation**; and this is very common.

BEGINNINGS.—Among the Protozoa it is possible to study the beginnings of many different kinds of activity, such as movement and multiplication, digestion and feeling. The great difficulty is that so many different kinds of activity go on within a very small compass. There is not the division of labour that has been established among the groups of cells in higher animals. The Protozoön is like a one-roomed house with many different activities going on at once in the same limited space; the multicellular animal or Metazoön is like a house of many rooms—each room for a particular purpose.

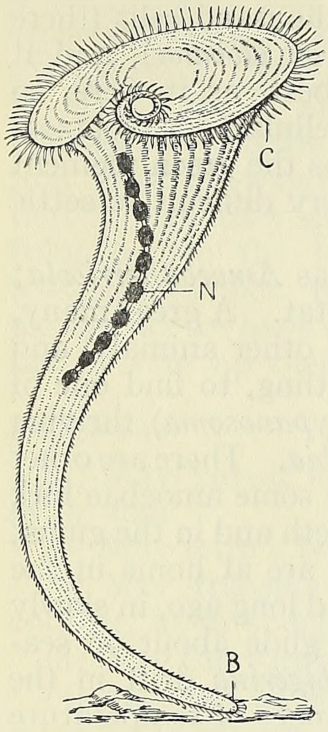


FIG. 10. *Stentor*

In this Protozoön there are cilia over the whole surface and specially large cilia (C) in a spiral wreath round the mouth. N is the large nucleus. There are also several minute nuclei. B is the 'base.'

Still, one can see in many a Protozoön the beginning of the setting apart of a contractile thread or of a sensitive spot, and so on. There is also the beginning of fertilization and of the distinction between male and female. There is also the beginning of behaviour, as when a large amoeba hunts a small one, or when a trumpet animalcule (*Stentor*) tries one method after another of solving a little problem. The experimenter allowed a shower of microscopic dust to sink upon the Stentor within its sheltering sheath. The Stentor bent a little to one side; but that was of no avail. The Stentor reversed its lashes or cilia and wafted the particles away from its mouth; but they continued to fall. The Stentor retracted itself into its sheath; but when it expanded again, the shower began once more to fall. Then, in the fourth place, the Stentor crept out of its sheath and swam away. Thus, among the Protozoa, we are on *the threshold of behaviour*.

EXEMPT FROM NATURAL DEATH.—Among ordinary animals there are three kinds of death. First, there is *violent* death when some part of the animal is fatally broken, or when the whole creature is devoured by an enemy. Protozoa are not in any way exempt from this kind of death. They do not live a charmed life.

Secondly, but less frequently in Wild Nature, an animal may be killed by an intruding parasite, perhaps a microscopic microbe, which eats a hole in it, or blocks a passage, or produces a poison. But parasites very often establish a 'live-and-let-live' compromise with

their host, and microbes dangerous to their usual hosts are very rare in Wild Nature. The Protozoa are not much troubled with this kind of *microbic* death. If a dangerous microbe finds its way into a Protozoön, it is usually digested forthwith. This is interesting because most multicellular animals have, as we have mentioned, among their cells certain wandering amoeboid units, called phagocytes (p. 38), which engulf and digest intruding bacteria.

But there is a third kind of death—*natural* death, to which all ordinary animals are subject. **Natural Death** is due to the slow mounting-up of arrears of wear and tear, especially in hard-worked organs. Work done always means expenditure of energy, and it also tends to produce wear and tear in the parts concerned. This is made good in various ways, by food, by resting, and by processes of repair or becoming young again (*rejuvenescence*). In ordinary animals the recuperation is imperfect and debts accumulate. In the Protozoa the repair is perfect—the whole animal is so simple—and the Protozoa are therefore *on the whole immune from natural death.*

GENERAL CHARACTERS.—Most of the Protozoa are very minute animals, single cells, without 'body,' organs, or tissues, but each is quite complete in itself. Most of them live on still smaller organisms, both plants and animals, or on organic particles disintegrating from other creatures that have died; but a great many are parasitic. Most of them live in water, both fresh and salt, but many can endure dryness for a considerable time. They multiply by dividing into two (fission and budding), or into many units (spore-formation). The life-history often includes the fertilization of one individual by another, the 'conjugation' or union being either total or partial. There are three great subdivisions: Infusorians, Rhizopods, and Sporozoa. A few form colonies of cells, taking a step, as it were, towards multicellular animals (*Metazoa*).

SOME IMPORTANT RHIZOPODS.—There are many thousands of different kinds of Protozoa and we cannot do more than select a few that are representative. A good general account of the various classes will be found in the *Cambridge Natural History* or in two special books on Protozoa, one by Minchin and the other by Calkins.

AMOEBAE.—These common animals are mostly found in ponds and ditches, gliding along the surface of the mud or on a stone. But there are several different kinds or species, and while *Amoeba proteus* lives in ponds, *Amoeba terricola* occurs in damp earth, and *Amoeba buccalis* is sometimes found in man's mouth. Against a dark background an amoeba can often be seen with the naked eye as a minute speck, and a common size for a pond amoeba is a hundredth of an inch in maximum length. But one cannot make anything of an amoeba without watching it many times under a good microscope.

The structure of a common amoeba is indicated in the figure.

How does the amoeba stand as regards the five everyday functions? (1) **Contractility** is diffuse. The living matter can contract in any direction, whereas the threads or fibres that make up a piece of muscle can contract only in the direction of their length. An active amoeba is always changing its shape (though not its size), and that is why

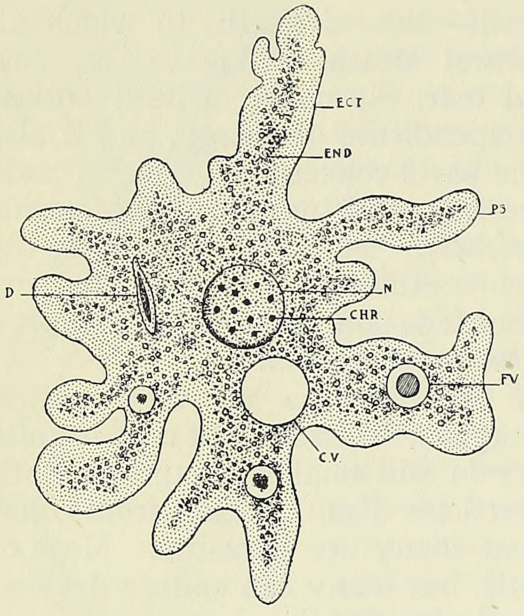


FIG. 11. *Amoeba proteus*

ECT. Clear mobile outer living matter or *ectoplasm*, sometimes showing radial striation.

END. More granular inner lining matter or *endoplasm*. The granules are partly nutritive substances in reserve and partly waste-products and undigested particles.

FV. *Food-vacuoles*, droplets of water surrounding food-particles which have been engulfed. A solid particle is shown in process of digestive disintegration.

CV. A *contractile vacuole* that increases in size and then bursts. It probably gets rid of dissolved nitrogenous waste; in other words, it has an excretory function.

D. A *diatom* or single-celled plant, with a flinty shell, that has been taken in as food.

PS. A blunt finger-like outflowing process, called by the old-fashioned name *pseudopodium*, which means 'false foot.' The pseudopodia are used in locomotion and in capturing food.

N. The kernel or *nucleus*, containing readily stainable bodies, called *chromatin granules*, CHR.

Roesel von Rosenhof, one of the earliest observers of the amoeba, called it in 1755, 'the little Proteus,' or the Proteus animalcule, after a mythical Greek personage who was ever changing from one form to another. There is great difficulty in understanding the movements of an amoeba, but the clear outermost zone of the living matter (that touches the water and the substratum on which the animal glides along) is very mobile. More internally there is a streaming of granules, and it has been observed that recognizable particles pass along the upturned surface in the direction in which the amoeba is moving, disappear over the front, and reappear at the posterior end. This suggests a sort of caterpillar-wheel movement or that of a 'tank.' The amoeba is said to glide along, but perhaps 'roll along' would be a more appropriate description. When an amoeba is moving on the

mud in a desultory sort of way, its course is a loose spiral, like that of a man swimming blindfold, but it must be understood that the amoeba is attracted by certain things, such as food and surfaces, and repelled by others, such as some chemical in the water or too intense illumination. When it is moving rapidly it gets up a pace of some six hundred microns per minute. A micron, μ, is a thousandth of a millimetre, and a millimetre is about one twenty-fifth of an inch. So the amoeba cannot be said to rush along! (2) **Irritability.** As we have just mentioned, the amoeba is attracted by some conditions and repelled by others. This irritability is not situated in any particular part of the amoeba; like its contractility it is diffuse. When an amoeba is isolated in water it sends out slender processes on many sides, as if it were feeling for some surface on which to creep. The irritability is also shown when an amoeba pursues a smaller amoeba ' with hostile intentions,' for they are sometimes cannibals. We say ' with hostile intentions ' since it looks like that, but we are only guessing when we speak of the amoeba's mind. Perhaps its inner or mental life comes and goes in flashes. But it is certain that a large amoeba may pursue a small one, capture it, lose it, pursue it again, recapture it, and lose it once more. If we were a small amoeba, and a big one (like the size of an elephant compared with man) were to come ' tanking' after us, turning as we turned, we should not, could we think, have any doubt as to the big one's ' intentions.' But the fact is that the amoeba is just on the threshold of animal behaviour. It is probably a very ancient animal, but it has not learned much yet.

As to (3) **Nutrition,** the pond amoeba feeds chiefly on unicellular algae, such as diatoms, and on the particles of decaying plants. Two of the blunt outflowing processes surround the plant or particle and engulf it by uniting; and this may occur at any part of the amoeba's surface. It is all mouth just as it is all muscle. As the pseudopodia (see Fig. 11) close on the diatom, a bubble of water is included, and this accounts for the food-vacuoles. Some digestive ferment from the living matter of the amoeba attacks the food inside the vacuole, so that it is dissolved and chemically changed. This digested food is then absorbed into the living matter, adding to the amoeba's capital. Both proteins and fats are found in the living matter. We may define **Digestion** as a fermentation process by which the food is dissolved if it is solid, and, in any case, chemically changed so that it more readily becomes part and parcel of the living capital.

All living involves a combustion or oxidation of carbon-compounds, and it is therefore necessary to keep up a supply of oxygen. The amoeba absorbs this from the surrounding water. As the result of the oxidation there must be carbon dioxide, and since this is poisonous it must be got rid of. These two processes make up (4) **Respiration,**

which may be defined as taking in oxygen and getting rid of carbon dioxide. This is seen at its simplest in amoebae, where it is effected by diffusion, oxygen seeping in and carbon dioxide seeping out.

There remains the fifth everyday function—(5) **Excretion**, which means a getting-rid of dissolved nitrogenous waste. Living matter always contains proteins, which are nitrogenous carbon-compounds, and the activity of life involves a breaking-down of these proteins. The result is the formation of nitrogenous waste, which has to be removed. There may also be nitrogenous waste due to unused portions of the dissolved nitrogenous food. The first kind of waste might be compared to the minute particles that get worn off the quickly moving wheels of an oil-engine, and the second kind to unconsumed by-products of the oil. It should be noted that physiologists do not use the word excretion for the getting-rid of the coarse remains of undigested or indigestible food from the food-canal. When that is expelled from the body of a many-celled animal, it may be called excrement, but the word **excretion** should be restricted to the removal of dissolved nitrogenous waste. In most animals this is chiefly the work of the kidneys, which are usually present from worms onwards; in the amoeba it seems to be mainly the work of the contractile vacuoles, but some of the waste may pass out by diffusion. When the amoeba has engulfed a diatom and has digested its contents, the flinty shell is left. In the course of the streaming of granules this indigestible particle passes to the posterior end and gets left behind. But, as we have said, this is not excretion in the strict sense.

Let us now sum up the everyday functions of the amoeba:

CONTRACTILITY: diffuse, but especially in the outflowing and in-drawing of pseudopodia; including superficial movement and deeper streaming.

IRRITABILITY: diffuse sensitiveness to food, chemicals, surfaces, and other stimuli.

NUTRITION: ingestion by pseudopodia, digestion in food-vacuoles, absorption from food-vacuoles.

RESPIRATION: diffusion of oxygen in, and of carbon dioxide out, at any point.

EXCRETION: removal of dissolved nitrogenous waste, chiefly by the two contractile vacuoles.

Here it may be noted that there seems to be a continual give-and-take between the kernel or **nucleus** and the surrounding substance. There is genuine living matter in the general cell-substance (**cytoplasm**) and in the nucleus, but the most complex protein material of the amoeba is the **chromatin** of the nucleus. In ways that are not understood, the nucleus is essential for the continuance of growing and

feeding, yet an amoeba bereft of its nucleus can live for a considerable time.

LIFE-HISTORY OF AN AMOEBA.—It is often convenient to sum up the life-history of an animal in a circle; and this may be done for an amoeba.

If we start with a small-sized representative of one of the kinds of amoebae, the first chapter is **growth.** And the condition of growth is that income be greater than expenditure. If the amoeba is increasing the amount of its living matter, it must be finding plenty of food. It reaches a size which is the best and safest size. This is called the **limit of growth** (1 in the figure), and for an amoeba it may

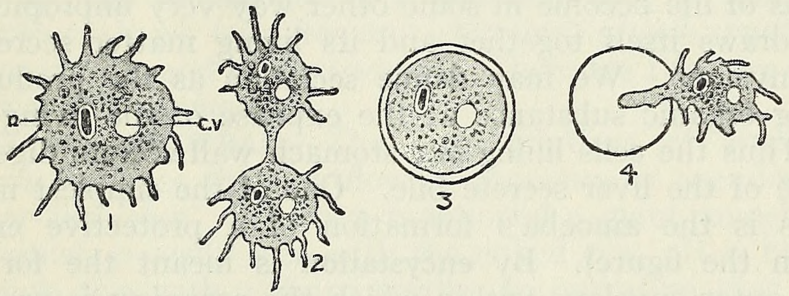


FIG. 12. SOME STAGES IN THE LIFE-HISTORY OF *Amoeba*

be one-hundredth of an inch in length and breadth. Its thickness is much less. Most animals show this limit of growth, and one thing it means is that the amount of living matter has become as large as the surface can readily keep alive. In spherical cells the volume increases as the cube of the radius, the surface only as the square. When it has attained 'the best size,' the cell obviates risks by halving its volume, and this means a proportionate gain of surface. This law does not apply to the amoeba so strictly as to a regularly shaped cell, for the amoeba can increase its surface by elongating its outflowing processes. But it applies in a general way; and another reason for the limit of growth is that the processes of life are no longer balanced when the amount of cell-substance becomes large in proportion to the nucleus. It is not surprising that some amoebae and other Protozoa have more than one nucleus. There is a giant amoeba, called *Pelomyxa,* sometimes found in duck-ponds, which has numerous nuclei. There are two reasons, then, why amoebae do not grow larger and larger indefinitely: there must be a proportion between volume and surface, and between the nuclear material (**nucleoplasm**) and the general cell-substance (**cytoplasm**).

When the amoeba has reached its limit of growth it tends to divide into two. *It multiplies by dividing.* No doubt the dividing (or **fission**) is due to some instability, but it is far from being a disorderly breaking into two: the nucleus (*a*) divides first, the two 'daughter'

nuclei separate, the part between becomes narrower, the isthmus breaks, one amoeba has become two. A half-sized amoeba (2 in the figure) may then proceed to become full-sized. This is the ordinary way in which amoebae multiply. Occasionally, however, many divisions may take place within the amoeba, so that numerous minute amoebae are formed and eventually set free. This is called **spore-formation,** the forming of numerous minute units in limited time (division following division rapidly) and in limited space (within the parent cell). Each of these minute amoebae would in time grow to the normal adult size.

The third chapter is entered upon when the pool dries up or the conditions of life become in some other way very unpropitious. The amoeba draws itself together and its living matter secretes a protective envelope. We may define **secretion** as the production of a non-living organic substance at the expense of the living matter of a cell. Thus the cells lining our stomach wall secrete digestive juice and those of the liver secrete bile. One of the simplest instances of secretions is the amoeba's formation of a protective envelope or cyst (3 in the figure). By **encystation** is meant the forming of a resistant outer envelope within which the organism is protected and can remain for a long time quiescent. The amoeba can wait for weeks till the rain refills the pool. Sometimes spore-forming takes place within the shelter of the cyst.

When the amoeba is once more moist, that is to say when water has diffused through the cyst-wall, the living matter becomes active again. The result may be a bursting of the envelope and the amoeba emerges (4 in the figure), none the worse for its rest, indeed with a new lease of life. This renewal is called **rejuvenescence,** which means becoming young again. The opposite is ageing or **senescence,** which is due to the mounting-up of the unrepaired results of wear and tear. In complicated many-celled animals there are many processes of rejuvenescence (such as rest, sleep, change), but ageing always wins in the long run. The amoeba, however, is so simple that it can continually make good its wear and tear, and thus enjoys a sort of **organic immortality.**

A few observers have seen another chapter in the life-history of amoebae, namely two individuals uniting to become one. This often occurs among the Protozoa, but it is rare among amoebae. It is called **conjugation,** which may be defined (among animals) as a total and permanent, or partial and temporary, union of two Protozoa or of special cells produced by these. Sometimes the two conjugating cells are quite indistinguishable, sometimes a small unit works its way into a large one, reminding us of what occurs in ordinary animals where a minute sperm-cell fertilizes a much larger egg-cell. It is

plain that conjugation is not a way of multiplying, for there is no increase in numbers. Indeed in total conjugation there is a decrease, for two become one. Conjugation should be called a kind of reproduction, not a mode of multiplication. Its meaning will be discussed in describing the life-history of the slipper animalcule (*Paramecium*). It should be noted that conjugation is common among single-celled plants as among single-celled animals, but whereas it never occurs in many-celled animals, it is continued among the simple multicellular Algae (seaweeds, etc.) and Fungi (moulds, etc.). Thus two opposite cells of two threads of the common freshwater Alga called *Spirogyra* may conjugate, the contents of the one cell passing over into the other.

To sum up, the life-history of a common kind of amoeba, like *Amoeba proteus*, shows four frequent chapters: *growth, multiplication* (fission), *encystation*, and *rejuvenescence*. There are two rare chapters: *spore-forming* and *conjugation*.

RELATIVES OF AMOEBAE.—The near relatives of amoebae are called *Lobosa*, because their outflowing processes or pseudopodia are blunt, finger-like *lobes*. We have mentioned a giant amoeba, called *Pelomyxa*, which is easily seen with the naked eye. It is big enough to be cut into two with a sharp needle, an operation that does not seem to trouble it at all! Even stranger is the fact, which we have verified, that two Pelomyxas can be mixed together with a needle so that they form one large unit. This shows vividly enough how far away these Protozoa are from ordinary animals, yet it corresponds to the grafting that is possible with the freshwater hydras or even with tadpoles. In ditches there is often a little amoeboid Protozoön, called *Difflugia*, which surrounds itself with a vase-like encasement of microscopic pebbles. When no other material was available it has been known to make a transparent case of glass splinters! Another not uncommon form is *Arcella*, which has a neatly made shell, a little like the top of a toadstool in shape.

SUN ANIMALCULES.—Mostly in clear fresh water are the beautiful sun animalcules or *Heliozoa*, distant relatives of the amoebae. From a transparent sphere the living matter radiates out in stiff processes, which capture small organisms. Some sun animalcules have spicules of flint, others are without any skeleton. Two well-known kinds are called *Actinophrys* and *Actinosphaerium*.

FORAMINIFERA OR CHALK-FORMING ANIMALS.—These are beautiful Protozoa, encased in shells usually made of limestone, but sometimes composed of foreign particles or of an organic substance called chitin (see INDEX). A few occur in fresh water; most live on the floor of the sea, from shallow water downwards. Several families, e.g. the *Globigerina*, are well represented in the surface waters of the open ocean. When these are killed by changes of temperature or the like, they sink in a

slow rain through the miles of water to become 'Foraminiferal ooze' on the floor of the Deep Sea, and they also form part of the food-supply of some of the smaller animals of the great abysses. A consolidation of great quantities of Foraminifera on the floor of ancient seas resulted in thick chalk deposits, such as the cliffs at Dover. The living matter of the Foraminifera flows out in interlacing threads from the mouth of the shell or through pores all over the surface. The limestone shells are often of great beauty—like vases, turrets, fans, and mitres, often with a curious suggestion of the enormously larger shells of sea-snails and Nautili. It is interesting but puzzling to see that the architecture of the firm shells of limestone that many of the Foraminifera make, is repeated in other forms that make shells of microscopic grains of sand, which are fastened together with some organic cement. It is difficult to know what words to use in speaking of the architectural activity of minute brainless animals like Foraminifera, but some of them adjust sponge spicules, fragments of sea-urchin test, and other foreign particles, in a way that would be called in a higher animal the skilful use of materials. Many of the Foraminifera are the size of pinheads, but not a few are much larger. Some fossil forms called *Nummulites*, very abundant in certain limestone rocks, were as large as shillings or half-crowns—giants indeed among the Protozoa.

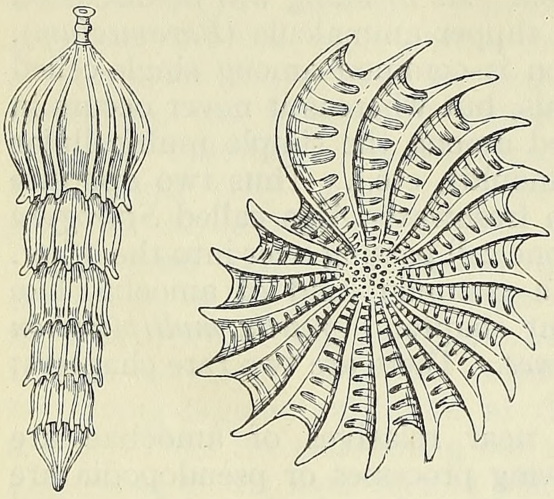


FIG. 13. FORAMINIFERAN SKELETONS (after Haeckel)

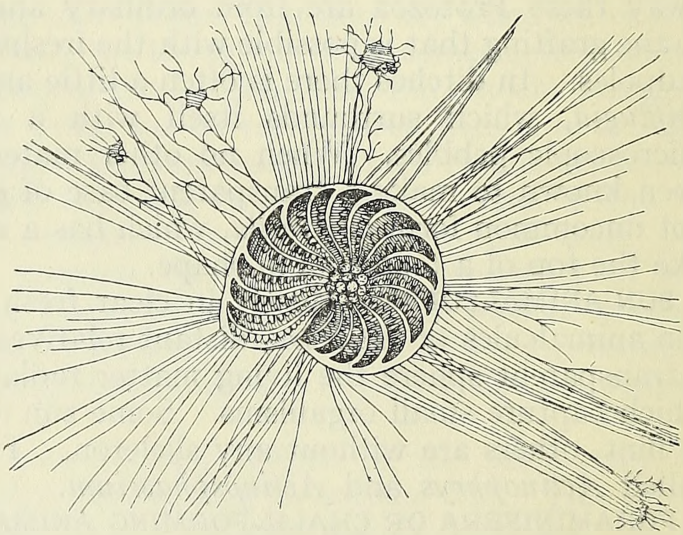


FIG. 14. A FORAMINIFER (*Polystomella strigillata*), WITH INTERLACING PROCESSES OF LIVING MATTER FLOWING OUT ON ALL SIDES

More complex still are the *Radiolarians*, mostly with shells of flint, but sometimes of the clear organic substance called acanthin. A few

have no skeleton at all. There is usually an internal shell, made of a material like chitin (see INDEX), separating the 'central capsule,' with the nucleus or with several nuclei, from the outer, more foam-like, portion of the living matter, from which there radiate outwards numerous delicate threads, rarely interlacing. Most of the Radiolarians are smaller than pinheads, but there are some that become as big as split peas by forming colonies of numerous cells embedded in a common jelly. All are marine, and most live in the well-lighted surface waters of the Open Sea. There is a good reason for this, for they live in partnership with unicellular Algae that use the sunlight in building up sugar and other carbon-compounds (see SYMBIOSIS). But some Radiolarians live below the surface waters at various depths, and others are actually abyssal. Just as 'Foraminiferal ooze' is formed from the down-sinking of Foraminifera that have been killed in the surface waters, so there is a rain of dying Radiolarians that forms another kind of 'ooze.' This **ooze** may be defined as an accumulation of minute dust-like particles on the ocean floor; it consists of microscopic shells or pieces of shells of different kinds, often with some remains of living matter. It is due to the settling down of what might be called 'the dust of the sea.' In its softer forms it has been described as 'like butter in summer.' Vast tracts of the floor of the Deep Sea, which occupies more than half of the whole earth's surface, are covered with ooze. But at one place there will be more Foraminiferal ooze, at another place more Radiolarian ooze, and besides these there is Pteropod ooze, made of the delicate shells of certain Open-Sea molluscs called 'sea-butterflies.' There is also Diatom ooze, consisting mainly of the flinty shells of the unicellular plants called Diatoms that are very abundant in the Open Sea. Finally, to complete in a simple way this note on DEEP-SEA DEPOSITS, there is often an abundance of what is called 'red clay.' It is neither red nor clay, but a fine powdery stuff made by a final breaking-down of mineral materials—all sorts of things reduced to their lowest terms for the time being. To sum up:

Deep-Sea Deposits

Foraminiferal ooze. *Pteropod ooze.*
Radiolarian ooze. *Diatom ooze.*
Red clay.

Sunken animals are soon devoured to the last crumb. Only very hard pieces, like sharks' teeth and whales' ear-bones, are left.

MARINE HAUNTS.—Before we leave this subject, we may note, for the sake of clearness, that the haunts of animal life in the sea are:

(1) *the Shore area or littoral area,* the relatively shallow water, well lighted, with seaweeds growing; (2) *the Open Sea or pelagic area,* the well-lighted surface waters and near-surface waters quite away from the shore; and (3) *the Deep Sea or abyssal area,* which is always taken to mean the dark, cold, quiet waters on the floor, or near the floor of the abysses, which may be as much as six miles from the surface. Not much is known of the intermediate waters, between the depth where the light fails, and the bottom still perhaps miles away.

SUMMARY OF RHIZOPODS.—Looking backwards, we may sum up the survey of the more or less amoeboid Protozoa, often called technically the Rhizopods or *Sarcodina*:

Rhizopods

Amoebae and the near relatives of amoebae	*Lobosa.*
Sun animalcules	*Heliozoa.*
Chalk-forming animals and their relatives	*Foraminifera.*
Flint-shelled forms and their relatives	*Radiolaria.*

Before going on to some other important Protozoa, we interpolate two short articles, one on **Chalk** from the natural history point of view, and the other on **Symbiosis,** which means an internal mutually beneficial partnership between two living creatures of different kinds. Chalk comes here because it has most to do with Foraminifera, and Symbiosis because it is so strikingly illustrated by the Radiolarians.

CHALK.—In various parts of the world, such as the Downs in the south of England, there are great deposits of chalk (calcium carbonate, $CaCO_3$) which were formed on the floor of ancient seas. They are particularly characteristic of the geological ages that came between the Jurassic and the Eocene, which are therefore called Cretaceous (i.e. 'chalky'). In many cases the white chalk consists largely of the limestone shells of Foraminifera, but there is often a mixture of other materials. Indeed there are great differences in the purity and in the softness of the chalk, but the old-fashioned blackboard chalk is a very good sample. The modern blackboard chalk in sticks is a manufactured article, consisting mainly of calcium sulphate. While it is useful to compare the ancient chalk-forming with the deposits of Foraminiferal ooze now going on in some parts of the floor of the Deep Sea, there is this difference and difficulty that there is no warrant for supposing that chalk-beds like those forming the cliffs of Dover were laid down in great abysses. They were probably deposited at depths between one and two thousand feet, which would not be reckoned as really Deep Sea.

SYMBIOSIS (literally a living together; *syn,* together; *biosis,* living) is a mutually beneficial internal partnership between two living

creatures of different kinds. It may be between an animal and a plant, as in most Radiolarians; or between one animal and another, as in the case of the wood-digesting Infusorians that inhabit the food-canal of white ants; or between two plants, as in the case of lichens.

Most Radiolarians have as partners numerous unicellular plants belonging to the class of Algae. These minute organisms used to be called ' yellow cells,' but they are *inmates* of the Radiolarian. They have a little chlorophyll and in the sunlight they are thus able to utilize the carbon dioxide formed inside the Radiolarian, which, like every other animal, is always using up oxygen and liberating carbon dioxide. As the Radiolarian is delicate and translucent, if not transparent, the sunlight gets ready access to the partner-plants, and so there is opportunity for the upbuilding processes (photosynthesis) common to all plants with chlorophyll. The partner-Algae are carried by the floating Radiolarians and they probably utilize the dissolved nitrogenous waste formed by their bearer. This would correspond to what an ordinary plant obtains from the soil-water by its roots. The advantage to the animal is the internal liberation of oxygen from the partner-plants, and if things are not going well the animal can digest the plant! Radiolarians are exceedingly successful Open-Sea animals, abundant as individuals and represented by perhaps five thousand different kinds (or *species*). It seems very likely that their success is in part due to their symbiosis.

The partner-Algae in Radiolarians are technically called *Zoöxanthellae*, and they occur in various other animals, such as the little green worm called *Convoluta* that is abundant on the flat beach at Roscoff in Brittany (see CONVOLUTA, in the INDEX). Another kind of partner-plant is called *Zoöchlorella*, which occurs in the green freshwater hydra, the green freshwater sponge, some sea-anemones, and many corals. A colony of green amoebae (*Amoeba viridis*) has been known to flourish for ten years without any food, the explanation being that the green colour was due to partner-Algae, and that they furnished internal food to the amoebae. Such a case must be distinguished from that of a few Protozoa which seem to have got possession of green colouring matter (chlorophyll) of their own. Thus the green kind of bell animalcule (*Vorticella viridis*) is green in its own right, and has no partners.

The **lichens** we see on trees and walls are double plants, produced by a partnership between Algae and Fungi. Each consists of the branching and interlacing threads of a fungus, and of alga-cells in the meshes. The Fungus partner fixes the plant and absorbs air, water, and salts. It also protects its partners from drought and injury. The greenish Alga repays its partner by manufacturing carbon-compounds in the sunshine. The two partners combine to make

reproductive bodies. We shall return to this very interesting case of symbiosis when we come to deal with plants. Yet we cannot leave lichens without noting that they succeed in surviving in very inhospitable places, such as the tops of mountains; and they are victorious because of their symbiosis.

OTHER EXAMPLES OF SYMBIOSIS.—Many insects, such as cockroaches, have partner yeast-plants in their food-canal, and these ferment hard and unpromising food. The young death-watches that tunnel in the wood of old houses have in connection with their food-canal two minute pockets crammed with yeast-plants, and these bring about the fermentation of the dryasdust food. In many backboned animals that depend on vegetable food, such as grass, the digestion of the cellulose (the substance that forms the cell-walls of plants) seems to depend on the activity of bacteria that live permanently in the food-canal. They may be called friendly bacteria, for they do good, not harm. The advantage to the partners is plain when we think of the abundance of food and the warm shelter of the food-canal. In some insects the partners in the food-canal are of the nature of moulds. In many white ants (*Termites*) the indispensable partners are exceedingly beautiful Infusorians. They are not known anywhere else and it is certain that they feed on the sawdust-like contents of the food-canal and change it so that it becomes available for the insects. By gently warming the Termites it is possible to kill all the partner-Infusorians in the food-canal without doing the insects any harm. But these individuals, though they continue devouring dry wood as usual, are unable to make anything of it, and soon die. The two-sided benefit is clear: the Infusorians are provided with food and shelter, but in return they make the food available for their Termite partner.

One of the most important forms of symbiosis is that between various plants and root-fungi (*mycorrhiza*). Thus most orchids are bound up with thread-like fungi that act as middle-men between them and the soil. In certain cells of the root there is a preparation of food material by the fungus threads; in other cells of the root the partner-threads are digested. In many orchids the seeds will not sprout unless they have been infected with the partner-fungus. Similarly, the success of the heather on the difficult half-ready soil of mountain and moorland is due to its being penetrated by a partner-fungus. This passes from root to stem, even into leaf and flower and seed. The heather succeeds because it is a 'firm.' Still more important are the bacteria that form tubercles on the roots of plants belonging to the pea and clover order (*Leguminosae*), for these bacteria make it possible for the plant to capture and utilize the nitrogen of the atmosphere. How this is done remains a riddle, but there is no

doubt as to the fact. We see, then, that there are many different kinds of internal partnership or symbiosis and in very diverse corners of the world of life. Symbiosis differs from external partnership or *commensalism*, e.g. between hermit-crab and sea-anemone, in being an *internal* partnership. It differs from parasitism in being *mutually* beneficial. To sum up:

Symbiosis

(1) *Between animal and plant*, e.g. Radiolarians and their partner-Algae; or many insects and their yeasts.

(2) *Between animal and animal*, e.g. Termites and the partner-Infusorians in their food-canal.

(3) *Between plant and plant*, e.g. Lichens; Heather and Fungus; Leguminous plant and Bacteria.

SOME IMPORTANT INFUSORIANS.—Among the very active Protozoa which are called Infusorians, some move by means of an undulating lash or flagellum or by two or three flagella. The movement of a flagellum is something like that of a snake in the water. The night-light (*Noctiluca*), that makes the summer seas luminescent at night, is a Flagellate about the size of a small pin's head. Very much smaller is the Flagellate (*Trypanosoma*) which causes sleeping sickness in man when he is bitten by an infected tsetse fly in tropical Africa.



FIG. 15. *Trypanosoma gambiense*, THE PROTOZOÖN CAUSING SLEEPING SICKNESS

BL, blepharoblast; FL, free end of flagellum; FR, flagellum attached to edge of an undulating membrane; N, nucleus.

But there are other Infusorians that have numerous living lashes or cilia which waft them swiftly along. The motion of a cilium is alternate bending and straightening, such as one may mimic by sharply bending one's arm at the elbow, and then straightening it again. It is a beautiful sight to see under a good microscope how the cilia beat in harmony, like the oars in a racing boat. The slipper animalcule or *Paramecium* is a good example of a ciliated Infusorian. It should be noted that some of the Flagellates and Ciliates are fixed to water-weed and the like throughout the greater part of their life; in such cases the lashes are used to waft food into the mouth. There is also a small group of Infusorians (*Suctoria*) in which the lashes have been changed into tentacle-like structures that grapple minute Protozoa that pass by. A common example is *Acineta*. To sum up:

Chief Groups of Infusorians

FLAGELLATES, e.g. *Noctiluca*, Monads, *Euglena*, *Volvox*.
CILIATES, e.g. Slipper Animalcule and Bell Animalcule.
SUCTORIA, e.g. *Acineta*.

INFUSIONS are simply the results of soaking parts of plants in some liquid, e.g. water. The liquid dissolves out some of the chemical constituents of the plant material. Thus tea is an aqueous infusion, where the dissolving-out of the palatable *theine* is helped by having the water hot. When the leaves are left soaking too long, some tannic acid is also dissolved out and the tea is spoilt. Now Infusorians get their name because they occur abundantly in infusions, and the question arises why this should happen. When cut flowers have been left standing for some time in a glass of water, the appearance of the liquid changes. It becomes turbid and it often has a stale smell. This means that there is a decomposition of the fluid through the agency of bacteria. These may have been lying on the surface of the plants, or they may have been wafted on from the air, or they may have been in the water to begin with. They feed on the organic matter in the fluid and they congregate on the immersed parts of the cut flowers. They multiply with prodigious rapidity, so that a million may soon be produced from one. But if a drop of the turbid water be examined under the high power of the microscope, it will be seen that there are Infusorians as well as bacteria. Where did the Infusorians come from? A few may have been present in the water, and others may have been lying in a latent state in chinks or cracks on the skin of the plants. Resting stages of various minute Infusorians, such as Monads, are sometimes carried about in the air. It may also be that some were landed on the plants when they were watered in the garden. In any case the outcome is that the infusion soon contains a large population of lively Infusorians.

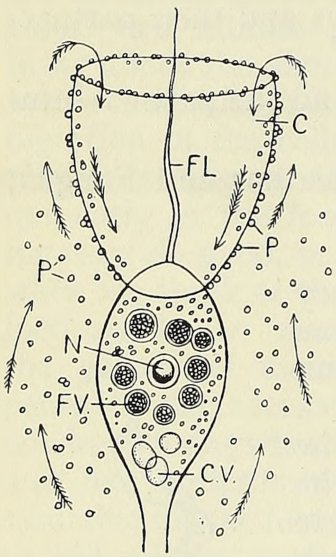


FIG. 16. A FLAGELLATE INFUSORIAN. ONE OF THE CHOANOFLAGELLATA, OFTEN CALLED A MONAD

C, collar; CV, contractile vacuoles; FL, flagellum; FV, food-vacuole; N, nucleus; P, food-particles. The arrows represent the direction of flow of the water in which the animal lives.

SUCCESSION OF LIVING CREATURES IN A HAY INFUSION.—If we gather a handful of dry grass from the side of a pool in a meadow, and let it soak in water, we soon have an interesting population of microscopic organisms. If some dry hay that has fallen off a cart

be soaked in water from a pool, we get the same result. As we have said, the organisms that multiply rapidly in the infusion must have been represented in or on the plants, or in the water, or in both ways. For no case is known of living creatures appearing except from pre-existing living creatures of the same kind. Observation and experiment warrant the statement, *Omne vivum e vivo:* Every organism comes from a previous organism of the same kind.

In most cases, however, there is a succession of events; thus slipper animalcules may not become noticeable until a week has passed. A common succession is the following: first, bacteria that decompose parts of the plants; second, monads, very minute flagellate infusorians, that feed on the result of the rotting; third, slipper animalcules, that feed mainly on the bacteria; fourth, a dying away of the populations till nothing active is left, unless there be a few amoebae gliding about on the débris at the foot of the vessel.

THE SLIPPER ANIMALCULE.—There are at least ten thousand different kinds of Protozoa, and there are several different kinds of slipper animalcule or *Paramecium.* But we may conveniently speak of the animal in the singular, for the various species differ from one another only in minute details. The slipper animalcule is just visible to the naked eye as a whitish speck when it is swimming in a glass vessel illumined from the side and held against a black background. It is about a hundredth of an inch in length, and it is counted as a giant among the Protozoa! In spite of its smallness, it has been very successfully studied, and the investigations have thrown light on many difficult problems. One of its most successful investigators (Professor L. L. Woodruff of Yale) quotes an appropriate sentence from Lamarck: ' The most important discoveries of the laws, methods, and progress of Nature have nearly always sprung from the examination of the smallest objects which she contains, and from apparently the most insignificant inquiries.'

Something of the structure of the slipper animalcule may be learned from the diagram (Fig. 17).

It may be useful to contrast Paramecium with Amoeba:

AMOEBA	PARAMECIUM
Naked, no rind or cortex.	With a rind or cortex.
No ' mouth.'	A definite ' mouth ' and ' gullet.'
No definite shape.	Definite in shape.
Moves slowly by ' pseudopodia ' or blunt outflowings.	Moves quickly by cilia or lashes.
No mooring-threads.	With special protrusible mooring-threads called *trichocysts.*

AMOEBA	PARAMECIUM
One kind of nucleus.	Two kinds of nuclei: a *macronucleus* controlling everyday activities, and a *micronucleus* (or two), of importance in reproduction.

The slipper animalcule is far more active than the amoeba; it is also more controlled; it shows division of labour in having two different kinds of nuclei. It may be said, in short, to be more highly evolved than the amoeba, though it is not any larger.

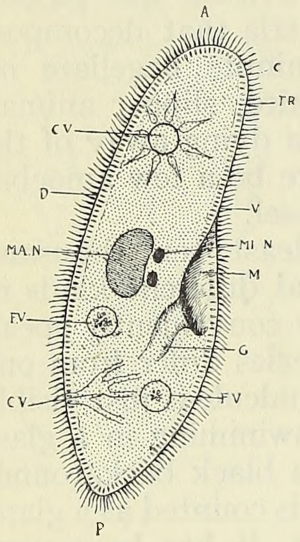


FIG. 17. *Paramecium*, THE SLIPPER ANIMALCULE

A, anterior end; C, cilia; CV, contractile vacuole; D, dermis; FV, food-vacuole; G, gullet; M, mouth; MA N, macro- (large) nucleus; MI N, micro- (small) nucleus; P, posterior end; TR, trichocyst; V, vestibule.

LIFE-HISTORY OF THE SLIPPER ANIMALCULE.—(i) **Growth.** If we start with a half-sized individual, the first chapter is growth. The Paramecium feeds largely on bacteria, which it wafts into its mouth with its cilia. A definite limit of growth is usually reached.

(ii) **Multiplication by fission.** At the limit of growth, perhaps a hundredth of an inch in length, the slipper animalcule divides into two. The nuclei divide first, lengthening out like dumb-bells, and separating towards the two ends of the animal. The dividing plane is crosswise, behind the mouth, and slightly slanting. One of the halves goes off with the mouth; the other half has to make one, which does not take long. The half-sized individual then proceeds to feed and grow, and it may be ready to divide on its own account in ten hours. Thus generation succeeds generation very rapidly. The bacteria, which represent transformed rottenness, are reincarnated in the form of millions of slipper animalcules—a simple instance of a **nutritive chain.**

(iii) **Conjugation.** Two slipper animalcules unite closely, mouth to mouth; the large nucleus disappears for the time being; the small nucleus divides; there is an exchange of micronuclear elements; then the two individuals separate and there is reconstruction of the two nuclei. This is **conjugation**—partial conjugation, an exchange of portions of the small nucleus. It is a kind of reproduction, not a mode of multiplication; and it promotes vigour and variability in the stock. In some cases its place is taken by a breaking-down and a rebuilding of the nuclei—a sort of internal scrapping and reconstruction that is called **endomixis.**

When a slipper animalcule is isolated in suitable water, where it can feed, it soon divides into two, and these again divide, and so on till there are thousands. After a number of generations, however, in this lineage all descended from one (a **'pure line'**), things are apt to go wrong. The individuals show various symptoms of deterioration—in activity, appetite, size, and nuclear structure. They exhibit what is sometimes called 'depression'; they look as if they were growing old. They do not conjugate, and this is possibly because they are all alike, all descended from a single ancestor. If some are shifted into a 'wild' population, they may at once show conjugation. But although the members of a pure line do not conjugate with one another, they show the process of nuclear scrapping and reconstruction called *endomixis*. This may occur periodically, it may be once a month. It seems in some measure to take the place of conjugation.

The main reason for the deterioration of the isolated stock of slipper animalcules is that the water becomes poisoned with their waste-products, but, by taking ingenious and patient care, Professor Woodruff of Yale University has been able to continue a vigorous pure line for nineteen years with over eleven thousand seven hundred generations. This shows that conjugation is not absolutely necessary, though it is of frequent occurrence in natural conditions, and seems, as we have already said, to promote vigour and variability. It corresponds, in a far-off sort of way, to outbreeding in a herd of cattle, that is, to the introduction of 'fresh blood.' *Conjugation promotes vigour and variability.*

A Pure Line may be defined as a series of generations all descended from one individual, whether it be an isolated Paramecium or the seed of a self-fertilized bean-plant. In a less strict sense, the term is sometimes applied to the descendants of a single pair, among which there is only inbreeding and no crossing with other stocks. Pure lines have not yet been studied very long, but in some cases, like Paramecium and bean-plants, there is a striking uniformity from generation to generation. Individuals may differ, as when one bean-plant is taller than another, because the conditions of life can rarely be quite the same for all; but novelties that can be handed on to the next generation are in some pure lines conspicuous by their absence. Self-fertilizing flowers may illustrate the occurrence of pure lines in natural conditions. And it may be noted that transmissible little novelties or mutations are *exceedingly common* in the pure lines of snapdragons. So this is the very opposite of what holds for bean-plants.

(iv) **Quiescence and Revival.** To complete our story of the life-history of Paramecium, we must notice that in bad times, such as weeks of drought, when the water evaporates from the pool, some

of the individuals manage to creep into the crevices of plants or into other crannies. They do not encyst, as amoebae do, but they lie quiescent, and some of them become lively again when the rain refills the pool.

Many other Infusorians are of great interest. Thus the luminescence of the sea in the summer evenings is mainly due to *Noctiluca*, the night-light, a flagellate about the size of a small pin's head ($\frac{1}{25}$ in.). It is a giant among the Protozoa and propels itself in the water by means of a strong pig's-tail-like lash or flagellum. It is found in all the seas and is sometimes so abundant that the tide may leave a long line of millions stranded on a flat beach. In such cases they have just a suggestion of ruddy-brownish colour, and the line can be very distinctly seen. In the water a slightly bluish or greenish light comes from numerous minute points in the living matter, and is intermittent. It shines out when the little creature touches anything or is hurried by a wave. It is probably due to a rapid fermentation (see ANIMAL LIGHT). Noctiluca usually feeds on still smaller Protozoa.

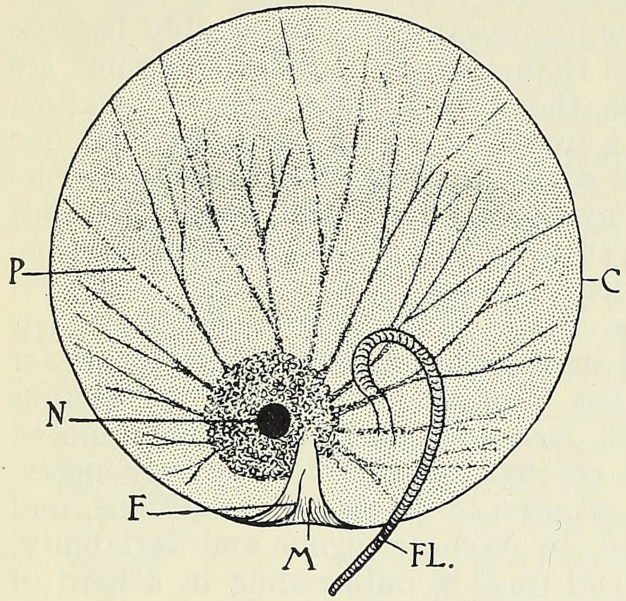


FIG. 18. *Noctiluca*

Diagram showing the structure of *Noctiluca miliaris*, the commonest cause of 'phosphorescence' in the sea. C, cell-wall; FL, strong cross-striated flagellum for driving organism through the water; F, small flagellum for wafting food in the mouth (M); N, nucleus; P, dense protoplasm which surrounds the nucleus but is much vacuolated towards the periphery, where it forms a continuous layer beneath the cuticle. The meshes of the protoplasmic network are filled with liquid.

Many other Infusorians of the sea are 'phosphorescent,' and some of them in the family of *Dinoflagellates* are so multitudinous that they give the water a reddish or brownish tinge. Forms like *Peridinium* and *Ceratium* are important even in the eyes of the 'practical man,' for they form a considerable part of the food-supply of the small Open-Sea Crustaceans that are eaten by daintily feeding fishes like herring, anchovy, and mackerel.

As a good instance of nutritive chains we may take mackerel, in regard to which it has been shown that the supply at Billingsgate market fluctuates with the amount of sunshine in spring. How does

this work out? The mackerel feed very largely on small Crustaceans of the open waters, such as those called *Copepods*. Thus the more abundant the Copepods the more will mackerel multiply, other things being equal. But the food-canal of the Copepod is found to be filled with Peridinid Infusorians and with minute unicellular plants called Diatoms (see INDEX). But, again, the numbers of these microscopic organisms of both kinds depend on the amount of sunshine, which many of the Peridinids seem to be able to utilize just as the Diatoms do in their ordinary plant-like fashion (see PHOTOSYNTHESIS). So the linkage runs: the more sunshine, the more Peridinids and Diatoms; the more of these (the living stock of the sea soup), the more food for Copepods; and the more do the mackerel flourish. This illustrates the way in which matter is always passing from one embodiment or incarnation to another—the **Circulation of Matter.**

Many of the Flagellates are green in colour, and are often claimed by the botanist as little plants. One of the commonest causes of the **green water** often seen in ditches and puddles is a Flagellate called *Euglena viridis*, about $\frac{1}{250}$ in. in length. It moves rapidly by means of an undulating lash or flagellum that protrudes out of the mouth, and also by a peculiar wriggling, due to waves of contraction in its living matter. It contains minute partner-Algae called *Zoöxanthellae* similar to those which we have already spoken of in connection with Radiolarians (see SYMBIOSIS). Thus Euglena seems to be an Infusorian that is green because of its partner-Algae. But there are a few Protozoa in which the green pigment chlorophyll belongs to themselves and is not due to any green partner-Algae living inside them; this is true of one of the green bell animalcules (*Vorticella viridis*), and of some of the very minute *Monads*. In some of the Monads (e.g. *Sphaerella nivalis*), so minute that they get wafted about in the air, the green colouring matter is masked by red, and when they sink to the ground they produce ' red snow ' or ' bloody rain.' Let us make a little summary in regard to **green animals:**

Green Animals

(1) Green colour due to internal partner-Algae, with chlorophyll, as in *Euglena*, green freshwater sponge, green *Hydra*, green sea-anemones, green corals, green *Convoluta* worm.

(2) Green colour due to chlorophyll belonging to the animal itself, as in *Vorticella viridis*.

(3) Green colour due to some pigment quite different from chlorophyll, as in the green worm *Bonellia*.

(4) Green colour due to a physical effect, the pigment present being

not green, but some other colour, as in green beetles, green woodpecker.

(5) Green colour due to green Algae growing on the outside, as in the shaggy hair of the tree-sloth.

Volvox is another very interesting kind of flagellate Infusorian, for it forms a many-celled spherical green colony. It does its best, so to speak, to get out of the class of Protozoa, and some naturalists

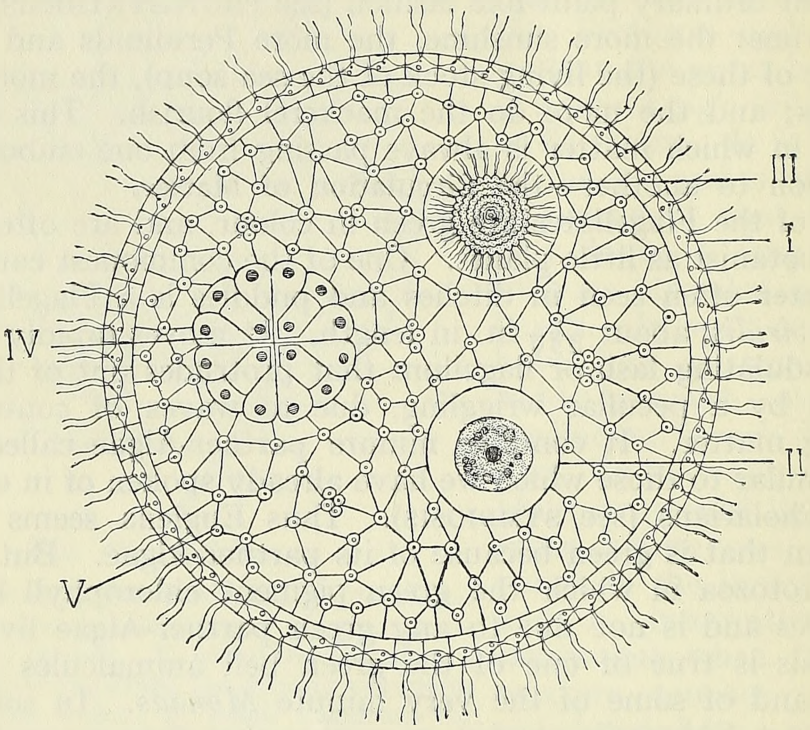


FIG. 19. *Volvox*

I and V, biflagellate individuals; II, ripe ovum; III, a ball of sperms; IV, a daughter-colony developing.

regard it as a free-swimming plant—a green Alga. It may be the size of a pin's head, so it can be easily seen with the naked eye as it rotates in the water of a pond, a canal, a pool or a water-barrel. It has a foundation of jelly-like material, firmer towards the surface, and in this outer zone there are numerous minute green cells, connected together by bridges of living matter. In *Volvox globator* there are about 10,000 of these minute units; the number is 500–1,000 in *Volvox aureus* and *minor*. Each unit or cell has a nucleus, two projecting flagella by which the creature moves, two contractile or pulsating vacuoles, and an eye-spot.

This living green globe of pinhead size rotates in the water, but it does not roll, for one part of the sphere is usually kept in front.

It is interesting in many ways. If it is a Protozoön it is a multicellular Protozoön; it has begun to form a 'body.' If it is an animal, it is able to feed like a plant, in virtue of having chlorophyll. If it is a Protozoön, it is striking in sometimes showing special reproductive cells—egg-cells and sperm-cells—though it may at other times multiply asexually, for a body-cell may divide and re-divide to form a daughter-colony inside the parent. Some of the sexual colonies are male, others female, others both. So there is a strange variety in this creature.

Another common and beautiful Infusorian is the **bell animalcule** (*Vorticella*), that often grows on the stems of freshwater plants, forming a white fringe readily visible to the unaided eye. Each individual is like an inverted bell on a long flexible handle; and round the mouth of the bell there is a wreath of cilia which waft in the food-particles.

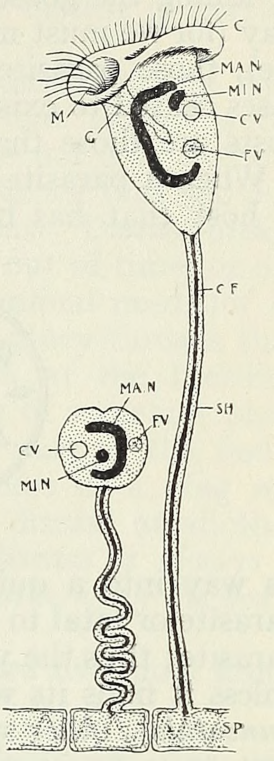


FIG. 20. *Vorticella*, THE BELL ANIMALCULE

C, cilia; CF, contractile fibre; CV, contractile vacuole; FV, food-vacuole; G, gullet; M, mouth; MAN, macronucleus; MIN, micronucleus; SH, sheath; SP, the alga, *Spirogyra*, to which the animals are attached.

SOME IMPORTANT SPOROZOA.—All the Sporozoa are parasitic and some of them do much harm when they get into hosts that are unaccustomed to their presence. Among the worst are the **malarial organisms** that cause various kinds of malaria in man, while others inhabit animals such as chimpanzees, cattle, horses, dogs, birds, and lizards. The malarial organisms (*Plasmodium* by name) are blood parasites that enter the blood corpuscles and destroy them, causing dangerous fever. Man is infected by being bitten by a mosquito (of the kind called *Anopheles*) which has been itself infected by biting a patient suffering from malaria. Thus the mosquito is the carrier or vehicle of this serious disease. The chapters of the life-history in the two hosts are very complicated.

A few other Sporozoa may be noticed. Thus in almost every earthworm there are parasites, often visible to the naked eye, which belong to the genus *Monocystis*. By teasing a little piece of the largest reproductive organs in the earthworm (the seminal vesicles) and examining the preparation under the microscope, it is easy to find several stages in the life-history of Monocystis, especially the sphere that we have figured, full of minute canoe-shaped spores. In many cases there are numerous specimens of this parasite in one earthworm, and yet they do not seem to injure their host to any

appreciable extent. This is frequently the case with **parasites**; they establish a live-and-let-live compromise with their host, and one sees that it is not in the interest of the parasite to kill the creature on which it depends for shelter and sustenance. That would indeed be killing the goose that lays the golden eggs. To put it in another way (for we must not conceive of the parasite as if it *thought* about its life), those parasites that killed their customary hosts have in most cases ceased to exist, those parasites that did not kill their customary hosts are those that survive to-day.

When a parasite that has become accustomed to a particular kind of host that has become accustomed to it is transferred to or finds

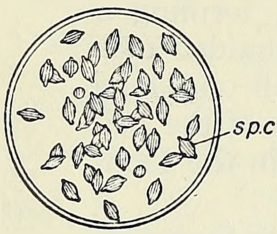


FIG. 21. SPHERICAL STAGE IN LIFE-HISTORY OF MONOCYSTIS, SHOWING CANOE-SHAPED SPORES, *spc*

its way into a quite different host, the result may be fatal to the parasite or fatal to the host. The new host may be unsuitable for the parasite; thus the young of the liver-fluke does not survive in Britain unless it finds its way into a particular kind of water-snail (*Limnaea truncatula*); other species will not serve. On the other hand, the new host may be so very suitable that the parasite runs riot and may become fatally abundant if it can multiply. This is the more likely to be fatal if the new host has no way of counteracting or checking the invader. Thus man is a new host for the deadly sleeping sickness animal, which the tsetse fly brings to him from some wild animal like an antelope. Therefore it goes hard with a man if he is infected with sleeping sickness. Let us sum up this note, which was suggested by the fact that the numerous Sporozoön parasites of the earthworm do not seem to injure it much: *Parasites tend to establish a liveable compromise with their accustomed hosts; they tend to be very injurious when they get into a new kind of host that has no way of checking their increase or counteracting their ravages.*

A common disease of young rabbits is due to a Sporozoön called *Coccidium*; a similar form attacks cattle on the Swiss pastures; and another species causes the 'oriental sore' among human beings in Asia.

Silkworm disease or *pébrine*, which used to be very serious, is due to a Sporozoön called *Nosema*, and a related kind occurs in hive-bees. The silkworm disease cost France many millions of pounds

and almost ruined the silk-growing industry until Pasteur discovered the cause of the mischief and showed how it can be checked. Whenever there is any trace of the disease the silk-moth is microscopically examined, and if the Nosema parasite is detected, the growers kill the insect and her eggs. Thus the spread of the disease is averted by continually nipping it in the bud.

PROTOZOA AND DISEASE.—To be diseased means that the vital processes of the body are disturbed in a way that threatens the wholeness or harmony of the creature. Disease is not a mysterious power that comes out of the unknown ('the pestilence that walketh in darkness') and seizes man and beast by the throat. **Disease** means that certain vital processes have got out of place, out of time, or out of tune. Thus what would be a disease in one animal need not be a disease in another, as may be illustrated by the gluey threads that exude from the kidneys of the male stickleback at the breeding season. And what is normal at a certain time or in a certain place may spell disease at another time or in another part of the body. Thus the bone-eating process by which the antlers of a stag are loosened off at the end of the winter might be a disease at another time or on another part of the body. But a *disease is always a deteriorative change that threatens the wholeness of harmony of the body.*

From the natural history point of view there are five chief kinds of diseases:

(*a*) Those due to something injurious in the surroundings; thus, too little light may help to give an animal 'rickets.'

(*b*) Those due to something wrong with the food, which may be deficient, over-abundant, or poisonous; thus lack of certain vitamins (see INDEX) may give sailors scurvy.

(*c*) Those due to something wrong with the habits, activities, occupations, and the like; thus too little exercise may make an animal injuriously flabby and fat.

(*d*) Those due to some deep-down disturbance in the germ or embryo from which the creature developed, as when there is some serious instability in the nervous system or in the hormone-making system (see INDEX).

(*e*) Those due to the intrusions of some other living creatures, such as malaria due to *Plasmodium* and sleeping sickness due to *Trypanosoma.*

Many diseases, such as plague, cholera and tuberculosis, are due to bacteria which belong to the plant world; others, such as malaria and sleeping sickness, are due to microscopic animals in the class *Protozoa.* Others, again, such as foot-and-mouth disease in cattle, are almost

certainly due to very minute living creatures which are so minute that they cannot be detected. As they pass through a very fine filter which keeps back bacteria, they are called **filterable** or **filter-passing viruses.**

Since diseases may be due to microscopic plants and to microscopic animals, it is convenient to have the word **microbe,** which may be applied to either. A microbe is a minute organism, either plant or animal, which causes disease when it finds its way into a suitable host. Thus we say that plague and cholera, sleeping sickness and malaria, are **microbic diseases,** though the first two are caused by plants and the other two by animals.



FIG. 22. *Spirochaete*

SP, *Spirochaete,* a Protozoön causing syphilis; FL, flagella.

Along with microbic diseases may be included those that are due to larger intruders, many-celled parasites, such as the liver-fluke in the liver-rot disease of the sheep, or the very small mite associated with ' Isle of Wight ' disease in hive-bees.

Two difficulties have to be faced: first, that it is doubtful whether all the dangerous intruders should be called parasites in the strict sense; and second, that the word disease is often used to include the defensive reaction that the body makes to the intruders. Let us consider these two difficulties very briefly. First, the deepest characteristic of a parasite is that it obtains its food without exerting itself, like a tapeworm in the intestine; and the difficulty is that an intruder like the Trypanosome of sleeping sickness is very energetic during part of its life in the blood. It is more like a microscopic beast of prey, devouring the host from within, as a lion does from without. We think that some of the intruders that are included along with parasites should be ranked as *predatory*. Second, when microbes begin to make themselves felt as intruders, the body answers back. The blood may produce a counteractive or **anti-body,** or the wandering amoeboid cells or phagocytes may engulf and digest the intruders. In these and in other ways the body defends itself, and in the second case mentioned there is **inflammation**—the battle between phagocytes and microbes. But this battle is not exactly the disease, it is a defensive reaction against the poisonous or destructive intruders.

How do the microbes kill? There are three chief ways in which the intruding microbes may destroy the body. (1) They may destroy living cells, thus making holes or breakages (**lesions**) in the tissues. Thus the tubercle bacillus may destroy part of the wall of the lung. Here may be included the destruction of blood corpuscles, as in

malaria. (2) When microbes multiply rapidly—and one may soon become a multitude of millions—they may block or clog a passage, like the diphtheria microbe in the windpipe. (3) Oftenest, however, the microbes kill by producing poisons or **toxins** which act like the venom of snake-bite.

Deadly Protozoa

(1) Among the SPOROZOA: the *Plasmodium* of malaria, the *Nosema* of silkworm disease, the *Isospora* of some kinds of dysentery.

(2) Among the RHIZOPODS: the amoeba that causes dysentery (*Entamoeba dysenteriae*), the amoeba of the gums (*Entamoeba buccalis*).

(3) Among the INFUSORIANS: the Trypanosomes of sleeping sickness, such as *Trypanosoma gambiense*; other Trypanosomes that cause serious diseases in cattle, camels, horses, and dogs; *Leishmania* that causes ' oriental sore ' and the disease called *kala-azar*.

We see then that formidable intruders come from each of the three great divisions of the Protozoa.

PROTOZOA AND THE WEB OF LIFE.—The parasitic and predatory Protozoa that we have mentioned are illustrations of ' the web of life '—the linkages that bind living creatures together. What other examples are there?

Protozoa are sometimes very useful partners, when they live in the food-canal of some animal and help to break down the food. Thus we have seen (p. 52) that there are very beautiful Infusorians always to be found in the food-canal of wood-eating white ants; they take in the minute particles of chewed wood and act upon them in some way, so that they become available as food for the insects. There are similarly useful partner Infusorians in the food-canal of herbivorous animals, such as horses.

Some Protozoa play a very important part in the economy of Nature by contributing largely to the **plankton** (the drifting population) of the sea and the fresh waters. They have a considerable share in feeding larger animals such as water-fleas.

When Protozoa have chlorophyll of their own or have partner green Algae living inside them, they are directly or indirectly able to build up carbon-compounds from carbon dioxide, water, and salts. And, apart from chlorophyll altogether, many of them utilize minute organic particles as their food, thus bringing débris back into the circle of life.

Protozoa may have partner-plants, as we have seen, but they may themselves be partners inside larger animals, as in the case of the Infusorians in the intestine of white ants.

Some of the Protozoa engulf bacteria and this may have various consequences according to the nature of the microbes. Who can trace the consequences that may follow when amoebae in the damp soil devour a large number of the soil-bacteria?

Open-sea Foraminifers and Radiolarians may be killed in large numbers by vicissitudes of temperature and the like, and when they sink to the great oceanic depths they contribute to the food-supply of that plantless world.

The down-sinking and subsequent consolidation of calcareous Foraminiferal shells on the floor of ancient seas has led to the formation of beds of chalk, as in the chalk cliffs of Dover. Remains of siliceous Radiolarians have also helped in the making of some rocks, such as Radiolarian cherts, from Silurian and Devonian strata onwards. From the later Tertiary deposits of **Barbados Earth,** Ehrenberg described no fewer than two hundred and seventy-eight species of Radiolarians. Thus we see that Protozoa have made large contributions to the solid earth, and we shall notice later on that the showers of Foraminifera from the surface waters have helped to raise the tops of submarine volcanoes to a level on which corals can grow.

LINKED TO MANY-CELLED ANIMALS.—The greatest gulf in Organic Nature, Agassiz said, was that between the one-celled and the many-celled animals, between the *Protozoa* and the *Metazoa*. But that gulf must have been crossed long ago, when the many-celled animals began. In some of the Protozoa we get hints of the way in which the transition was effected. For some Protozoa form loose colonies of cells. That is to say there is repeated division and yet the units remain connected instead of separating in the usual fashion. These colonies occur among Sun Animalcules, Radiolarians, and Infusorians; they show *the making of a body*.

Cells

WHAT IS MEANT BY A CELL?—When we first use the word 'cell' we think of the hexagonal compartments of a honeycomb, or possibly of the cells in which prisoners are confined or hermits meditate. The general picture that rises in our mind is that of a little compartment; and those biologists who first described and delineated cells had been looking at the minute box-like structures which are seen for instance when a thin slice of pith is examined under the microscope. But the early picture laid too much emphasis on the *walls* of the box or compartment, which are very clearly defined in most plant-cells, and too little emphasis on the *contents*, consisting mainly of living matter. In most animal cells the cell-wall is very delicate, and some cells are

quite naked. *A cell is a unit corpuscle or area of living matter, usually centred in a kernel or* **nucleus.**

If we prick our finger with a clean needle and let a drop of blood mingle with some salt solution on a slide; if we put on a cover-slip neatly, without letting air-bubbles in, and if we look at our preparation under the microscope, we see a multitude of minute cells, somewhat disk-like faintly yellowish-red blood corpuscles, and more irregularly shaped unpigmented white blood corpuscles. Each of these is a single cell, and there are many millions of them circulating in our blood-stream. The red blood corpuscles of man and mammals are exceptional in this, that after they are fully formed they show no nucleus. It is probable that the characteristic substance of the nucleus—**chromatin**—has been changed into infinitesimally small dust-like particles, which are distributed through the living substance—**cytoplasm**—of the red blood corpuscle. In other backboned animals, such as frogs, each red blood-cell has a very distinct nucleus, which can be made prominent by staining the blood with a particular dye.

If we take a plump leaf like that of hyacinth and break it across, and then pull the parts gently away from one another, it is easy to separate off a transparent skin. If we put a strip of this skin in water on a slide, cover it smoothly with a slip, and then examine it under the microscope, we see numerous somewhat rectangular cells, neatly fitted together to make a transparent pavement—the leaf-skin or **epidermis.** Each cell is a compartment full of living matter or **protoplasm,** which is centred in a spherical nucleus. It is more profitable to see a few cells for oneself than to read a hundred pages about them. Everyman his own biologist, as far as may be!

If we take a dry slide and draw it slowly over the surface of our lip, we are likely to rub off some of the flat tile-like cells that form the outermost skin. With the naked eye we may not be able to see anything except that the surface of the slide is not quite clear; but if we put on a drop of water and a cover-glass, and examine under the microscope as usual, we see the flat cells that are always being worn off our lips and replaced by others. Each is a little like a flat scale or squame, so the technical name for this outermost skin is **squamous epithelium,** the first word meaning 'scale-like,' and the second word 'a covering' or 'investment.'

It is interesting to snip off a small piece of the gill of an oyster or a mussel and look at it in a drop of sea-water under the microscope, for it shows under high power a multitude of living lashes or cilia. These are of great importance to the bivalve, for they keep up the currents of water carrying the microscopic organisms or organic particles which the creature uses as food. Covering the gills and

some other parts of bivalve molluscs, there is this **ciliated epithelium**, and as we look at it we should remember that the same kind of tissue lines the windpipe and the bronchial tubes leading to our lungs. It is also interesting to remember that the whole of the outer surface of a newly hatched tadpole is covered with the same kind of ciliated epithelium. Above the amphibian level among backboned animals there is no instance of *external* ciliation.

Another good illustration of cells is obtained by teasing up a little piece of animal ovary, such as that of a stickleback or a sea-urchin, which shows numerous spherical *egg-cells* or **ova.** Or a few eggs may be taken from under a female crab's tail, or from the vase-like egg-capsules that dog-whelks fasten to the sides of seashore pools. But in these cases the liberated egg-cells have begun to develop into embryos. That is to say, they are multicellular, no longer unicellular.

If one dissects a big earthworm it is easy to find two pairs of white sacs opening between segments 9 and 10, and 10 and 11, each about the size of the head of a large blanket-pin. They are called **spermothecae** and they are full of hundreds of *male cells* or **spermatozoa,** which have been received from another earthworm during the coupling. If one of these little sacs is burst on a slide with some weak salt-solution and examined as usual, the microscope shows myriads of delicate cells, like quivering pins. These are the sperm-cells or spermatozoa, in marked contrast to the much larger and usually immobile egg-cells.

A very useful thing to do is to take from the ditch a few threads of the very common freshwater alga called *Spirogyra* (see ALGAE). One of these threads looked at under the microscope shows a single row of rectangular cells with the chlorophyll or green colouring matter arranged in spiral bands. In this case it is not difficult to see the nucleus. The preliminary practical study of cells should also include the observation of some single-celled animals (see PROTOZOA) and single-celled plants (see PROTOPHYTA).

THE CELL-THEORY.—One of the foundation-stones of biology is the ' Cell-Theory,' which was first clearly stated in 1838–9 by Schwann and Schleiden, and about the same time by Virchow and Goodsir. The term ' cell-theory '—a translation of the German ' Zellen-Lehre ' —is not very fortunate, for there is nothing hypothetical about it. Perhaps ' cell-doctrine ' would be better; it is a generalization based on a multitude of facts.

The cell-theory or cell-doctrine includes three propositions. (1) *The first proposition* is this: Every living creature has a cellular structure; that is to say, it is either a single cell complete in itself (the Protozoa and the Protophyta), or it is composed of many cells and modifica-

tions of cells which make a body (from Sponges to Man, from many-celled Algae to Flowering Plants).

Some unicellular Protozoa, such as *Opalina*, a beautiful ciliated Infusorian that lives in the hindmost part of the frog's food-canal, have many nuclei—they are **multinucleate.** Another good example is the giant amoeba (*Pelomyxa*), found in some ponds, and easily visible to the naked eye. Some Protozoa and Protophytes form loose colonies of cells, well illustrated by the green ball named *Volvox* (p. 60), which differ from what we call ' bodies ' since there is almost no division of labour. They may be called **cell-colonies.** Another point is, that in some parts of many-celled animals, e.g. some of the simple worms, the demarcations between adjacent cells are very vague, a state of affairs called **syncytial.** Each nucleus may be taken to represent a cell, but the demarcation of cell from cell has not been effected. Similarly in the development of some animals, such as certain species of *Peripatus* (q.v.), the nuclei multiply but the cell-boundaries are not definite. Thus the whole embryo may be, for a while, what is called a **syncytium.**

These and other exceptional cases show us that hard-and-fast lines are unusual in the world of life; but they also suggest a useful idea. Useful but not easy. A very simple many-celled animal, such as the wheel animalcule or Rotifer called *Hydatina*, may have just about one thousand cells in its intricate little body. Many an animal, such as an earthworm, has millions of cells; we ourselves have millions of millions in our blood alone. In the surface layer or cortex of man's fore-brain there are five times as many nerve-cells as there are people living on the earth. Not unnaturally, therefore, we tend to think of a body as like a great city or community of cells. In some measure this is true—the body *is* a community of minute units of living matter, the cells. But the body of the many-celled organism starts from a single cell, the fertilized egg-cell, which soon divides into a group of cells, each with its nucleus. It may be that the reason a many-celled organism consists of myriads of cells of minute size instead of a few cells of large size, is that each nucleus can superintend only a small area of cell-substance or cytoplasm. The occurrence of many cells, each gathering round its nucleus, may be that it is only in this way that the living matter can be greatly increased in amount. When the living matter or protoplasm grows larger by taking in food, it would become unmanageable unless it were divided up into many units, each with its cell-membrane and its nucleus. What we are driving at is the idea that a condition of the growth of an egg-cell into an effectively large organism is that many cells be established as a means of securing not only division of labour, but coherence. The old Roman saying was: *Divide et impera* (Divide so as to rule); and something like this is seen

in the way in which a fertilized egg-cell divides into many cells. As the shrewd botanist De Bary put it: ' It is not that the cells make the plant; it is rather that the plant makes the cells.' In other words, the organism is not only a community of co-operant cells: it has segregated its increasing amount of living matter into many units or cells, for this is the secret of stability, complexity, and control.

(2) *The second proposition* is that the life of the body is the sum of the lives of the component cells. Among animals the work that is done, e.g. in obtaining food, is usually due to the muscles which are controlled by the nervous system; but if these are to continue doing their work they must be supplied with food and oxygen, and they must be kept from being clogged with waste-products. Thus digestive cells, oxygen-capturing cells, filtering cells, and so forth, are indispensable contributors to the life of the whole. This is the physiological side of the cell-theory.

It requires this saving clause, that just as the doings of a battalion are, in a sense, more than the sum of the actions of the individual men, since they are unified by a common purpose or by obedience to certain commands, so the body is unified or **integrated** in such a way that it works harmoniously. In the realm of organisms, the whole may be more than the sum of its parts. Sometimes it is the ' mind ' that acts as the *esprit de corps* unifying the body; sometimes, when there is no distinct evidence of an inner psychical life, all that we can say is that the body is integrated, or bound into unity and harmony, by the nervous system, the blood and the hormones (see INTEGRATION). In varying degrees the cells of the body have individual independence, and they sometimes mutiny (e.g. when they form **malignant growths**), but usually they are subservient to the common weal. In any case they are never to be thought of as comparable to the myriads of mites in a cheese, but rather to the myriads of honey-bees in a hive. They live a communal life. One must not make too much of the difference that the cells of the body are physically continuous, whereas those of an animal society are physically discontinuous, for many cells in a body, such as those of the blood, are free from one another; moreover there are many animal colonies whose members are physically continuous (see COLONIES).

(3) *The third proposition* included in the cell-theory is embryological. All many-celled organisms that multiply in the ordinary way start as single cells, which by repeated division form aggregates of cells or embryos, and gradually by continued multiplication and by division of labour build up a body. In the great majority of cases the many-celled animal or plant begins as a fertilized egg-cell; in some cases like summer green-flies and dandelions the beginning is an egg-

ell that does not require to be fertilized (see PARTHENOGENESIS). n some animals, e.g. many stinging animals and fluke-worms, the ertilized egg develops into an asexual form which buds off the sexual orm, and the same kind of **alternation of generations** occurs very lainly in all plants like mosses, ferns and horsetails. Other exceptions have to be made, as for animals that multiply *chiefly* by giving off buds, e.g. the freshwater hydra, and for plants that liberate relatively large reproductive structures, such as the bulbils of the iger-lily; but for the great majority of multicellular organisms the ell-theory holds: that the individual beginning is a fertilized egg-cell, which divides and re-divides to build up a body.

CHAPTER IV

SPONGES

The first successful many-celled animals—The simplest Sponges are like small vases—Complex Sponges—General characters of Sponges—Why Sponges are not regarded as plants—Life of a Sponge—How Sponges multiply—Some of the different kinds of Sponges—Classification—Sponges and the web of life.

THE FIRST SUCCESSFUL CLASS OF MANY-CELLED ANIMALS IS THAT OF THE SPONGES.—The life of the sponges is so much bound up with currents of water that pass in and out through pores on the surface that they have received the technical name **Porifera,** which means pore-bearers. Small pin-prick pores admit to ingoing canals; through the large holes, often with the diameter of a lead-pencil, the water passes out.

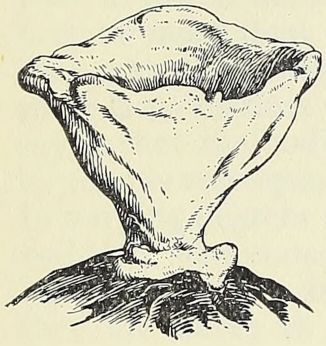


FIG. 23. CUP SPONGE

Thus a sponge may be compared to a city like Venice, for it is dependent on its canal system. The water that passes in carries microscopic food-particles and organisms; the water that passes out carries away the waste. Very minute free-swimming young ones may also be swept out in this way. But what is it that keeps the currents going? The answer is to be found in the ceaseless activity of certain lashed cells, often with beautiful transparent collars, belonging to the inner layer of the sponge. For it must be noted that when we pass from single-celled animals to many-celled animals (*Metazoön*, p. 36) we have to deal with cells in layers. The sponges, like the stinging animals (sea-anemones, corals, jellyfishes, etc.), have two layers of cells (**diploblastic:** *diplo*, double; *blastos*, germ) and between them an indefinite middle stratum (**mesogloea:** *meso*, middle; *gloea*, jelly).

THE SIMPLEST SPONGES.—A very simple sponge, such as one called *Ascetta*, is like a little vase, with a central cavity lined with the inner-layer cells with their collared lashes. The central cavity corresponds to a food-canal in a general way, but the opening at the top of the vase is an exit or exhalant opening—certainly not a mouth. Indeed, one of the most remarkable facts about sponges is that when the free-swimming young ones settle down, they fix themselves by what

might be expected to become the mouth. The exit opening at the top of the vase is unfortunately called the **osculum,** which means 'little mouth'; but there is *no mouth* in sponges; and, as we have mentioned, the microscopic food-particles are drawn in through pin-prick openings in the outer layer. The middle stratum of the wall of the vase is supported by needles or three-rayed spicules of lime-stone. Thus a simple sponge is a simple animal when compared with an earthworm, but a complex animal when compared with an amoeba.

COMPLEX SPONGES.—The most familiar type of sponge, however, is the bath sponge, and though what we use is only the skeleton, it evidently belongs to an animal very different from the little vase that we have just described. How then are we to pass from a simple sponge to a complex one? An important step is that a sponge often buds, and that the buds unite together. Thus a sponge is often more like a colony of animals than a single animal. The number of large exhalant openings often gives us an idea of the number of buds that have fused together to make up the sponge.

Another step is that the inner layer becomes folded into side-aisles, whose walls are again folded; and thus there arises a compli-cated system of canals and flagellate chambers. In many cases a strong outer rind is established with spacious porches beneath it; and the middle stratum of the sponge begins to show complications in its supporting skeleton and division of labour among its component cells. Thus some of the cells may become contractile, or muscular cells, and others binding or connective cells, and others colour-con-taining or pigment cells, and so on. This is indeed one of the points of general interest in sponges, that they show the beginnings of **tissues.**

A **tissue** may be defined as a group of similar cells with similar activities. Illustrations are a piece of skin, a piece of flesh or muscle, a piece of brain or nervous tissue, a deposit of fat, a slice of bone or of gristle. If an animal is compared to a city, then an organ would correspond to a department of the city, a tissue to a street of similar houses or shops, such as are sometimes seen in old-fashioned towns. To carry the comparison further, we may liken the cells of the body to the houses or shops, and smaller living units within the cells to the inhabitants themselves. It may be useful here to classify the chief kinds of tissues in higher animals:

Tissues (*or Groups of similar cells with similar functions*)

(1) NERVOUS TISSUE, e.g. of brain, made up of nerve-cells and their fibres, *not represented in Sponges.*

(2) MUSCULAR TISSUE, made up of long contracting threads or cells.

(3) LINING AND COVERING TISSUE (EPITHELIAL), e.g. skin, lining of food-canal, lining of blood-vessels.

(4) CONNECTIVE TISSUE, often binding together like the 'fascia' that envelops a piece of flesh; often supporting, like gristle and bones.

GENERAL CHARACTERS OF SPONGES.—We see then that sponges are multicellular animals without true **organs**, yet showing *tissues in the making*. They are fixed animals, and all but one family live in the sea. They are peculiar in many ways, e.g. in having no mouth, nothing very readily comparable to a food-canal, and no nervous system. The outer and inner layers of cells are not readily brought into line with the fundamental layers of cells (ectoderm and endoderm) in other many-celled animals. The canal system is also peculiar, and the collared lashing-cells that are of most importance in keeping the currents going are only hinted at in two or three other types of many-celled animals.

WHY SPONGES ARE NOT RANKED AS PLANTS.—The old naturalists regarded sponges as peculiar plants, and they are certainly plant-like in being fixed, in showing little visible movement, and in usually forming many buds. But why was the old view wrong? The answer is threefold: (1) the cells of sponges are like those of other animals, they differ from plant-cells in not being enclosed in walls of **cellulose** (a carbohydrate with the same empirical formula as starch, $C_6H_{10}O_5$); (2) they feed on solid particles in a way entirely different from that seen in plants, which absorb air by their leaves and soil-water by their roots; and (3) their fertilized egg-cells develop into minute free-swimming young ones, quite unlike any of the young stages of plants. These three reasons are enough to show that sponges are genuine animals.

LIFE OF A SPONGE.—An animal may be very active although it does not move about. Thus the acorn-shells or rock-barnacles in the shore pools are fixed animals, yet they spend a great deal of energy in wafting food-particles into their mouth by sweeping the water with their curl-like legs. The same is true of sponges, which are ceaselessly wafting the water through their canals. It comes out with considerable force in many cases and may make a little commotion on the surface of the water a foot above the sponge. They feed on unicellular plants such as Diatoms, just as oysters occasionally do; or on unicellular animals such as Infusorians; or on particles of broken-down creatures. These microscopic items of food are captured by cells on the walls of the canals, but especially by the collared flagellate cells, which often pass them on to amoeba-like cells in the middle stratum (see PHAGOCYTES). The sponge's amoeba-like cells are able to take over the food-particles from the lashing-cells, and

they can also transport and digest them. This kind of fact can be proved by feeding the sponge with some recognizable material, such as carmine particles or milk, and then killing it and cutting microscopic sections. The recognizable food-particles can then be detected in different cells in different stages of utilization. The freshwater sponges have symbiotic unicellular plants in many of their cells, and these are able to build up carbon-compounds in the sunlight. What the partner-plants have manufactured can be absorbed by the sponge (see SYMBIOSIS), which is an easy way of feeding! Many sponges have bright pigments that belong to themselves, and have nothing to do with partners. Some of these pigments seem to help in the capture of oxygen.

HOW SPONGES MULTIPLY.—Sponges grow large buds, but these are not separated off; they merely add to the size of the animal, just as new shoots add to a tree. Sometimes there is a formation of minute buds which are set adrift, and this is a way of multiplying that might be compared to the separation of little 'bulbils' from the stem of a tiger-lily. But the ordinary method of multiplication is by means of egg-cells which are fertilized by sperm-cells borne by the water from another sponge. The fertilized egg-cell divides and re-divides (**cleavage** or **segmentation**) and becomes a ball of cells—the **embryo.** This bursts the egg-membrane and acquires lashes or flagella, by means of which it swims away from the parent sponge. It is for a short time a free-swimming **larva.** But the ball or oval of cells becomes a two-layered sac which settles down and fixes itself. From this there is gradually developed a young sponge.

But we must define all these words. When a living creature produces another living creature like itself by separating off a considerable portion of its body as a bud, or fragment, or sample, that is called **asexual multiplication.** Examples: a freshwater polyp or hydra giving off a bud; a sea-anemone splitting into two; a simple worm multiplying by division. This is a somewhat slow and costly way of multiplying. It does not occur in higher animals.

When a living creature liberates or separates off egg-cells, each of which may develop into a new life when fertilized by a sperm-cell, usually liberated from another individual, this is called **sexual multiplication.** One of its advantages is that a great many young ones can be launched at once. Another advantage, not difficult to understand in a general way, is that the egg-cell contains the inheritance from the mother (the female parent), while the sperm-cell contains the inheritance from the father (the male parent), and thus fertilization means (among other things) the mingling of two inheritances, which may make for profitable (as well as unprofitable) new departures or variations.

Let us make a summary which may be improved later on, though it is quite accurate so far as it goes:

Asexual Multiplication

(1) Usually by separating off. (BUDS, e.g. Hydra; HALVES, e.g. Planarian worm; SAMPLE FRAGMENTS, e.g. Sea-anemone.)

(2) Occasionally by separating off 'spore-cells,' requiring no fertilization, e.g. in life-history of Liver-fluke.

Sexual Multiplication

(1) Usually by liberating and setting apart egg-cells (ova) and sperm-cells (spermatozoa), usually produced by female individuals and male individuals respectively.

(2) Occasionally the egg-cells do not require to be fertilized; thus a drone-bee has a mother, but no father.

This is called **parthenogenesis.**

This summary must be re-studied later on, for these things are not easily understood. It may be asked, for instance, whether multiplication by spore-cells, as in the life-history of the liver-fluke, or the fern plant, should not be included, with parthenogenesis, as a peculiar form of sexual multiplication.

As long as the young creature is not free, but is surrounded by an egg-membrane or an egg-shell, or something of the same nature, it is called an **embryo.** When the young creature is set free to fend for itself, being 'hatched out' from the egg-shell or the egg-envelope, it is either a larva or a miniature of the adult. The word **larva** is used when the liberated young creature is not like a miniature of the parent, but has to undergo some change (or **metamorphosis**) before it assumes the likeness of the full-grown form. Thus what comes out of the egg of a butterfly is a caterpillar; what comes out of the egg of a frog is a tadpole.

In mammals (milk-giving quadrupeds with hair) the conditions are very peculiar, for the embryo develops for a long time before birth in partnership with its mother. After the embryo has begun to put on mammalian characters and to live as a 'sleeping partner' within the mother, the word **foetus** is used. Let us try a summary:

The ovum develops into an embryo, which develops—

(*a*) until it is set free as a miniature of the adult;

(*b*) until it has remained for a considerable time in partnership with the mother (mammals);

(*c*) until it is set free as a larva, quite unlike the parent, and requiring a metamorphosis, or great change, before it becomes like the parent.

SOME OF THE DIFFERENT KINDS OF SPONGES.—Excepting the freshwater *Spongillids*, all sponges are marine; and here we may learn the lesson that if there are hundreds of representatives of a group in one habitat or haunt, and a few representatives in another, there is enormous probability in favour of regarding the first habitat as the original headquarters. There are peculiar cases to be specially accounted for, like the Marsupials in Australia, but on the whole the rule we have stated holds. No doubt, sponges were originally marine. The colonizing of the fresh waters was a second thought.

Many sponges live in shallow inshore waters, attached to rocks and shells and seaweeds. Among these may be mentioned the simple purse sponge (*Grantia compressa*), called after Robert Grant who first understood the canal system, and the crumb-of-bread sponge (*Halichondria panicea*), encrusting the rocks and showing very clearly the numerous exhalant apertures, like the craters of tiny volcanoes. Further from the tide-marks, but still in shallow water, the bath sponge (*Euspongia*) lives, especially on the Mediterranean coasts. The sponge fishermen wrench good specimens off the rocks by means of long-handled instruments like hay-forks, and the delicate tissues are allowed to decay and are then washed out. Fine sand is sometimes used in the cleaning process and the skeletons are eventually dried in the sun. A sponge is so simple in its structure that one may be cut in pieces and bedded out like a potato tuber, but the sponge fishermen have not time for this sort of thing. It may be noted, however, that if a purse sponge is minced into pulp, and even filtered through a piece of cloth, a small quantity of the débris will develop, in suitable conditions, into a perfect sponge. This shows that the microscopic cells of the sponge have the power not only of forming others like themselves, but of restoring the characteristic architecture of the sponge.

Sponges occur on the floor of the sea at all depths, and the dredgers and trawlers give popular names to some of those they bring up—mermaid's gloves, elephant's ears, sea-apples, and so on. An interesting small form called *Cliona* bores numerous holes in oyster shells, about the size of those made by a gimlet; and the perforated shells are often found on the shore, where they tend to get broken down into sand. Some of these small boring sponges have relatives of the same species that live freely, without adopting the burrowing habit, and it is interesting to find that these sometimes grow to a huge size. Another interesting form (*Suberites domuncula*) grows round the whelk or buckie shell that has been borrowed by a hermit-crab. It gradually dissolves the hard whelk shell, thus lightening the burden the hermit-crab has to carry, without making the shelter less effective. As the Suberites has a peculiar antiseptic smell, and a skeleton of thousands

of flinty needles, it is not a favourite article of food among marine animals, and the bright orange colour may serve as a useful reminder of its non-palatable qualities. All this will tend to make it a profitable partner for the hermit-crab. If it gets any benefit in return, it may be in being carried about from place to place by its partner, but against this must be put the great disadvantage of being left behind when the hermit-crab has become too large for the borrowed shell and has to flit into another. Unless the derelict Suberites on the whelk shell be discovered by another hermit-crab of suitable size, it is in rather hopeless state. Here it may be noticed that some of the shore crabs, like the sand-crab (*Hyas araneus*), fix small pieces of other sponges on their legs or carapace and thus disguise themselves, occasionally almost out of recognition. This mode of concealment is sometimes called **masking.**

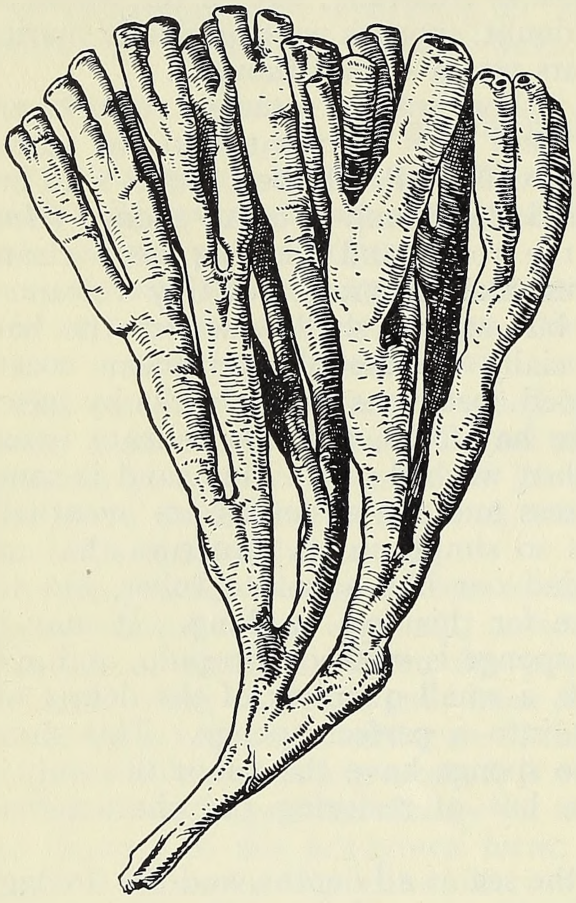


Fig. 24. Complex Sponge

Some of the finest sponges live in the Deep Sea, rising like fairy palaces from the ooze-covered floor of the great abysses. Such is Venus's flower basket (*Euplectella*), found in deep water off Japan. It is supported by an exquisite skeleton of flinty spicules and threads, sometimes rising to a height of a couple of feet. What we see is, of course, the cleaned siliceous skeleton, which was entirely covered during life by the delicate sponge-tissue—becoming brownish when dried. The skeleton is so delicate that it breaks in a child's fingers, yet the animal lives in the Deep Sea under the enormous pressure of several tons on the square inch. The explanation in this and in all similar cases is that the body of the animal is penetrated by canals or other passages containing the sea-water, so that the pressure is bound to be the same throughout. If a closed glass vessel is weighted and lowered into deep waters, it is shivered to powder; but an open vessel treated in the same way is unaffected, for the water in its interior is continuous with that outside, and the great pressure is the

same inside and out. Thus we find that all the Deep-Sea sponges and many other Deep-Sea animals are penetrable through and through with water. Another well-known abyssal siliceous sponge is the glass-rope sponge. Here the body is raised out of the treacherous smothering ooze on the end of a long stalk of flint-fibres twisted into a rope. And it is curious to find that this glass-rope is invariably bound together into firmness by a growth of small sea-anemone-like animals.

CLASSIFICATION.—Sponges may be conveniently grouped according to the nature of their skeleton. The simplest forms have spicules of limestone, e.g. the purse sponge. Many of the Deep-Sea sponges have spicules of flint, as in the case of Venus's flower basket. The bath sponge has a skeleton of somewhat silk-like threads, called **spongin,** without any spicules and therefore very useful for its familiar purposes. But a great many sponges, such as mermaid's gloves, have a spongin skeleton with which are associated large numbers of flinty spicules. It is plain enough why sponges of this type, though often suitable in shape and size, could not be used for toilet purposes; the spicules would act like sandpaper on the skin. Finally, but quite exceptional and very few in number, are the soft sponges, like *Halisarca*, with no skeleton at all. It is not difficult to understand that sponges that tried doing without a skeleton would not be likely to achieve great success, for they would be eaten up. The survival of a soft sponge, like Halisarca, has not been explained as far as we know; but there may be some quite simple reason for it, such as unpalatability. There are succulent, worm-like, sand-burrowing animals called *Enteropneusts*, which we shall come to later on, very appetizing in appearance, yet not much molested — perhaps because of a repellent odour of iodoform.

Phylum **Sponges or Porifera**

Class I. Calcareous Sponges; e.g. *Grantia* and *Sycon*.

Class II. Flinty Sponges with spicules with three axes; e.g. Venus's Flower Basket and Glass-rope Sponge.

Class III. Flinty Sponges with spicules with one axis or four axes, often with spongin; e.g. Mermaid's Gloves, Crumb-of-bread Sponge, Freshwater Sponges. The Bath Sponges with no spicules are included here.

Class IV. A few soft Sponges without any skeleton, e.g. *Halisarca*.

As to the origin of sponges, we may trace them back to the colonies of cells formed by some of the Protozoa. One of these many-celled colonies is called *Proterospongia* because of its likeness to a group of sponge-cells. It is highly probable that sponges evolved from colonies of Monad Infusorians, for some of these Monads are collared flagellate

cells like those which are characteristic of the lashing internal chambers of sponges, and are hardly ever seen in other types of many-celled animals.

Sponges were the first animals to be successful in having a body built up of thousands of cells, but they have not led on to anything else. They represent a terminus, a blind alley in evolution. Or we like to think of them as an eddy of skeletal beauty, for many of them, like Venus's flower basket, are masterpieces. If it be asked why sponges have not led on to any other kind of animal, part of the answer is to be found in the fact that when their free-swimming larvae settle down, they fix themselves mouth downwards—which is certainly not a progressive thing to do. Sponges are animals that have surrendered their mouth, and though this does not affect their own success, for they have multitudinous inhalant pores and feed on microscopic particles and organisms, it tends to close the door to further advance. There are some jellyfishes (*Rhizostomes*) that lose their mouth, and take in all their food by minute pores, but this does not affect the class to which they belong; it does not preclude further evolutionary advance. Another fatal defect in the organization of sponges is that they do not seem to have any nerve-cells. And there is no doubt that the possession of nerve-cells is an indispensable condition of progress.

It should be noted that there are some unfamiliar little animals called **Mesozoa** which are simpler even than sponges, and occupy a still humbler position in the series of many-celled animals. They are called Mesozoa because they are, as it were, midway between Protozoa and Metazoa. But the simplicity of some of them is perhaps due to parasitism, for *Dicyema* is a parasite of cuttlefishes and *Rhopalura* of brittle-stars and some worms. There are others, however, that live independently. We mention the little group here because some of them are possibly connecting-links between one-celled and many-celled animals, or hints at least of how the gulf was bridged.

SPONGES IN THE WEB OF LIFE.—Sponges are living thickets in which many animals play hide-and-seek. They are rarely eaten by other animals, but they afford good shelter. One of the cuttlefishes places its eggs carefully into pockets in the substance of a flinty sponge. *Cliona* bores in oyster shells and some sponges smother fixed animals, like zoöphytes, on which they spread. The crab called *Dromia* is often masked by growths of sponge, and the hermit-crab has an advantageous partner in the orange-coloured *Suberites domuncula*. The freshwater *Spongilla* has a profitable internal partnership with greenish unicellular algae, and there are other instances of this **symbiosis**. Finally, the bath sponges have been factors in civilization.

CHAPTER V

STINGING ANIMALS OR COELENTERA

General characters of Stinging Animals—The freshwater Hydra—Zoöphytes and Swimming-bells—Sketch of a Swimming-bell—The Regent's Park medusoid—Portuguese Man-of-war—Jellyfishes or Medusae—Sea-anemones and their relatives—Incipient Commensalism—Reef-corals and their relatives—Black Corals—Red Corals and their relatives—Precious coral—How corals feed—Sea-pens—The comb-bearers or Ctenophores—Survey of Coelentera.

GENERAL CHARACTERS OF STINGING ANIMALS.—There is no convenient English name, unless 'stinging animals' be accepted, for the large group **Coelentera**—which includes jellyfishes, sea-anemones and reef-corals, sea-fans and sea-pens, zoöphytes and swimming-bells. The curious word 'Coelentera' (*coel*, hollow; *enteron*, gut or food-canal) means that the only large cavity inside a sea-anemone or inside a jellyfish is the food-canal. In other words, there is no body-cavity (or **coelom**) such as we find in almost all animals above the Coelenterate level. A true **body-cavity** is a space between the food-canal and the body-wall—a space occupied in higher animals by a variety of organs such as heart and lungs, stomach and liver. In a mammal, to make the point quite clear, the body-cavity (or coelom) is divided into the *chest-cavity*, containing heart and lungs, and the *abdominal cavity*, containing stomach and intestine, liver and pancreas, and so on. But stinging animals have no body-cavity.

When we look at jellyfishes, with their transparent disks throbbing in the tide, or at sea-anemones nestling like chrysanthemums in the niches of the rocks, we are at once struck by a peculiarity of symmetry as compared with most other animals. The stinging animals are **radial**, whereas most animals are **bilateral**. An animal like an earthworm, a lobster, a beetle, a mussel, a fish, a frog, a tortoise, a bird, or a mammal, has a right and a left side, a dorsal and a ventral surface. There is only one cut that will divide the animal into two symmetrical halves. We often see this halving—through the median dorso-ventral plane—in the half-sheep or half-bullock hung up in the butcher's shop. But, until we begin to observe very precisely, jellyfishes and sea-anemones are the same all round; there is no right side or left side; there is *radial symmetry*. A simple Coelenterate, like the freshwater *Hydra*, or one of its simple seashore relatives, like *Tubularia*, is actually *the same all round*, and it could be halved by an indefinite number of vertical cuts. Any one way of halving

would be as good as another! This is perfect radial symmetry, like that of a tumbler.

Another general character for which the sponges have prepared us is that the stinging animals have two fundamental layers of cells in their body, whereas higher animals have three. The outer layer, making a sort of skin, with muscle-cells, nerve-cells, stinging-cells, and so on, is called the **ectoderm**, or, in the embryo, the *epiblast*. The inner layer, lining the food-canal with digestive and absorbing cells, is called the **endoderm**, or, in the embryo, the *hypoblast*. Between the two in all the higher animals, from worms to mammals, there is a middle layer, called the **mesoderm**, or, in the embryo, the *mesoblast*. But in Coelentera, except in the class of comb-bearers or *Ctenophores*, there is no mesoderm. There may be a structureless middle lamina or a middle jelly into which some cells may wander, but there is no definite middle layer. Therefore the term **mesogloea** (see p. 72) is used; and it is very well illustrated by the jelly of the jellyfish.

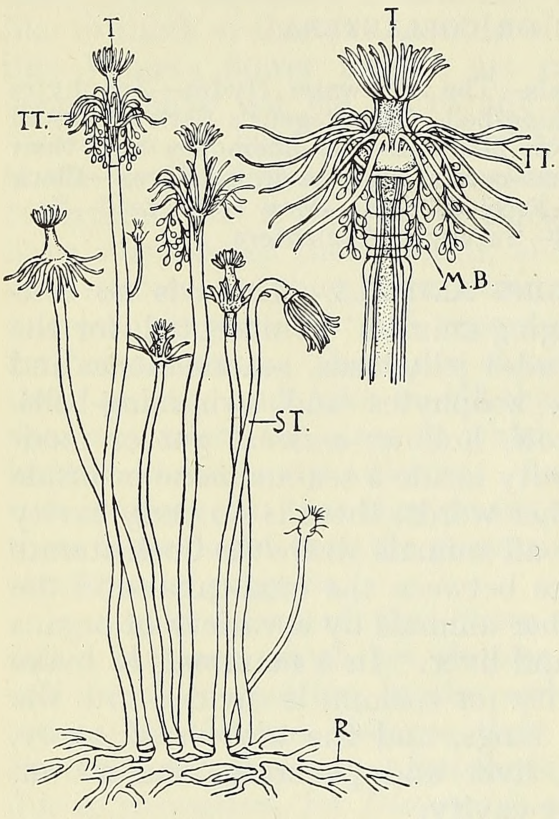


FIG. 25. *Tubularia*

MB, medusoid buds; R, roots; ST, stem; T, oral tentacles; TT, aboral tentacles.

Almost all the stinging animals have stinging-cells which eject a microscopic lasso, sometimes poisonous and paralysing, sometimes for grappling small prey. The stinging-cells or nettle-cells are absent from almost all the Ctenophores, where their place is taken by adhesive cells able to catch the small animals that serve as food. These stinging-lassos are not always strong enough to pierce our skin, and yet they may be effective enough on small animals, either for benumbing or for gripping. If we touch the tentacles of the common red sea-anemone with our finger, we do not feel any pain, though we may notice that our finger is being gripped. But if we kneel down on the rock and try the sea-anemone with our tongue, we may be able to verify the stinging power of *Coelentera*. Some of the large jellyfishes sting very severely and it may take days before a badly stung bather recovers. He has had hundreds of minute injections of a

poison that covers each of multitudinous stinging-lassos. The cell that drives out its lasso, to many times its own length, never recovers from the explosion. It is like a gun that can only be fired once; it is replaced by a new stinging-cell. Just as sponges were marked by collared flagellate cells, so Coelentera are marked by their **stinging-cells.**

Most of the stinging animals are also marked by the possession of **tentacles,** thread-like or finger-like, usually contractile, outgrowths which bear batteries of stinging-cells, and are generally useful in the capture of food. When we see an animal with many tentacles like feelers, we may be almost sure that it is a Coelenterate—one of the stinging animals.

Among the stinging animals there are two main kinds of body, which are called **polypoid** and **medusoid**; and in a strange way these are sometimes combined in one life-history. By the polypoid body is meant a fixed tubular animal with a crown of tentacles surrounding the mouth. By the medusoid body is meant a bell-like jellyfish-like animal; it is a form suited for free swimming. But to this we must return.

Among stinging animals there is a strong tendency to form colonies, among the members of which there is often division of labour. The colonies, such as the numerous **zoöphytes** that grow on seashore rocks and shells and seaweeds, are usually formed by repeated budding, and there may be hundreds of individuals sharing a common life. In some cases the colonies belong to the medusoid type and are free-swimming, like the Portuguese man-of-war; but here again the colony is formed by budding many times repeated.

Another tendency illustrated in great variety among the stinging animals is the tendency to form **corals.** This means that sedentary forms tend to lay down a very substantial skeleton, usually made of calcium carbonate (limestone). Indeed 'coral' is a name that is applied very widely to many different kinds of stinging animals that have not much in common except their stings and their hardness.

Let us sum up these general characters. The stinging animals are for the most part *radial*; they have usually *only two distinct layers of cells*; they have *no body-cavity*, their only cavity being their food-canal. They are almost always provided with *stinging-cells* and with *tentacles*. There is a strong tendency to form *colonies* and the sedentary types have a bias towards becoming *corals*. Thus we see that the stinging animals agree in some ways with sponges; that they differ in most ways from higher animals; and that they have very distinctive features of their own.

THE FRESHWATER HYDRA.—One of the simplest of the stinging animals is the freshwater *Hydra*, of which there are three well-known kinds—the green (*Hydra viridis*), the brown (*Hydra fusca*), and the

grey (*Hydra grisea*). They have wandered from the original home of stinging animals, which was no doubt the sea. All the stinging animals except about half a dozen are marine—and there are thousands of different kinds.

The favourite habitat of a hydra is on a water-weed, and it may often be found hanging head downwards from the little flattened disk-like shoot of the duckweed or *Lemna*, which is the second smallest flowering plant in Britain. A hydra is often towards half an inch in length of body, and its tentacles may be equally long or much longer. It is about the thickness of a thin pin, and it can contract itself into a minute plump knob, difficult to see against the plant, especially if it be the green hydra. It is indeed a very simple animal, with six to ten hollow tentacles around the mouth, and with no organs save the food-canal and the reproductive organs. These appear as little bulging knobs on the outside of the tubular body.

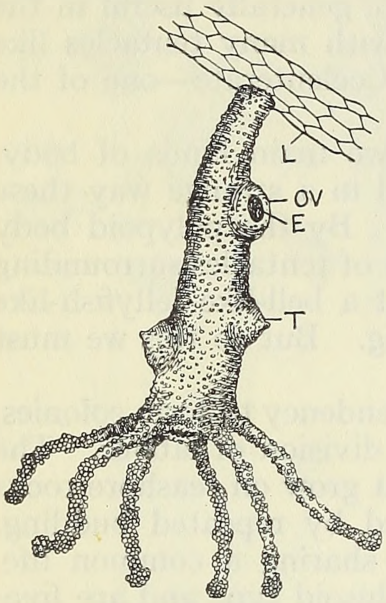


FIG. 26. *Hydra*
E, egg; OV, ovary; T, testes; L=stem of water-weed.

The hydra can shift its position (1) by alternately loosening its base and fixing its mouth and tentacles, (2) by loosening its base and writhing its body in the water, and (3) by protruding amoeboid processes from the cells of its base, so that it glides very slowly on the plant to which it is attached. Without shifting its attachment it can sway its body and tentacles in the water, and contract or elongate both.

It feeds on minute animals, which it grapples with its microscopic lassos, sometimes apparently paralysing them. Then the tentacles bend to the mouth and may be seen pushing in the minute booty. Animals as large as water-fleas (*Daphnia*) and river-worms (*Tubifex*) are sometimes seized, but smaller creatures must be more profitable. Motionless bodies are not seized unless they are very appetizing, like little fragments of blotting-paper dipped in beef-juice. A green hydra can utilize some of the carbon-compounds made by the partner-Algae in its inner-layer cells.

As regards more detailed structure, it may be noted that Hydra is like a brick chimney two bricks thick. That is to say, it is a two-layered (**diploblastic**) animal. The outer layer or **ectoderm** includes covering-cells, muscular-cells, glandular-cells, stinging-cells, sensitive-cells, nerve-cells, and cells that fill up chinks, called interstitial. This shows what is meant by division of labour or **differentiation**; there are several kinds of cells, different in structure and in use

or function. Similarly for the inner layer or **endoderm**, there are numerous lashed cells, sometimes changing into amoeboid form, which engulf and digest food, and also keep up a current. Some of them have muscular roots like those which occur on the muscular cells of the outer layer, but running in a circular direction, not lengthwise as in the previous case. Thus the ectoderm muscle-roots make the

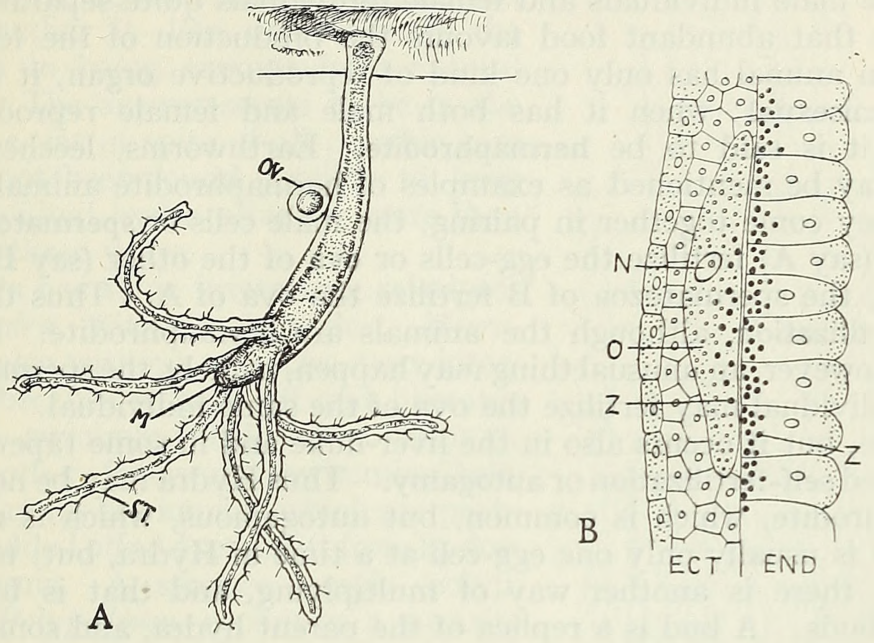


FIG. 27. *Hydra* AND ITS STRUCTURE

A, *whole animal.* OV, ovary; M, mouth; ST, stinging-cell or *cnidoblast*. B, *small portion of Hydra*, as seen under the microscope. ECT, ectoderm; END, endoderm; N, nucleus; O, ovary; Z, the symbiotic algae, *Zoöchlorellae* (see INDEX).

hydra shorter, while the endoderm muscle-roots make the hydra narrower. Near the mouth of the hydra, inside, there are some cells that seem to make a digestive secretion. A **secretion** is a non-living organic substance made at the expense of the living matter; and cells that secrete are said to be **glandular.** Thus the glandular-cells in the lining of our stomach secrete gastric juice which contains a ferment called pepsin. But Hydra can digest in a way that is lost in higher animals. Its inner-layer cells can engulf solid food-particles from the cavity of the food-canal and then digest them, just as amoebae might. This is called **intracellular digestion,** whereas in higher animals the food-particles are dissolved in the food-canal and thus absorbed in fluid form. This is **extracellular digestion.** Hydra shows both. **Digestion** in general may be defined as dissolving the food by ferments so that it becomes fluid and diffusible. We have given these few details in regard to the structure of Hydra because the

little creature is such a good illustration of the beginning of intricacy in many-celled animals.

An individual hydra is often both male and female at once, the male organs (**testes**) appearing as several minute protuberances a little way below the bases of the tentacles; the female organ (**ovary**), with a single egg-cell, forming a larger knob further down. Sometimes there are male individuals and female individuals quite separate, and it seems that abundant food favours the production of the females. When an animal has only one kind of reproductive organ, it is said to be **unisexual**; when it has both male and female reproductive organs, it is said to be **hermaphrodite.** Earthworms, leeches, and snails may be mentioned as examples of hermaphrodite animals; but when they come together in pairing, the male cells or **spermatozoa** of the one (say A) fertilize the egg-cells or **ova** of the other (say B), and similarly the spermatozoa of B fertilize the ova of A. Thus there is **cross-fertilization,** although the animals are hermaphrodite. In the hydra, however, an unusual thing may happen, namely, the spermatozoa of an individual may fertilize the ova of the same individual. This is very rare, but it occurs also in the liver-fluke and in some tapeworms. It is called **self-fertilization** or **autogamy.** Thus Hydra may be not only hermaphrodite, which is common, but autogamous, which is rare.

There is usually only one egg-cell at a time in Hydra, but, to compensate, there is another way of multiplying, and that is by producing buds. A bud is a replica of the parent hydra, and sometimes the bud produces another bud on its own account, so that there may be three generations together—the original hydra, its offspring, and its grand-offspring. Some check comes to the food-supply, and the buds separate off as independent individuals. It is in this way that the pond is peopled with hydrae.

The brown hydra presses its gelatinous-sheathed egg against water-weed; in the green hydra and the grey the enshelled egg sinks to the mud of the pond. In all cases it remains quiescent for several weeks before active development begins, and in this state it may be carried by wind or by birds from one pond to another. After a slow development a minute hydra creeps out from its investment and fastens itself to water-weed.

The Abbé Trembley, who made the first careful study of the fresh-water polyp about 1750, called it Hydra after the mythical monster with which Hercules contended. What resemblance is there between the monster and a little creature half an inch long? When Hercules slashed an arm off the monster, it seemed that another grew in its place; and the Abbé Trembley found that if he cut his hydra into a few pieces, he got as many new hydrae. The piece must not be too small and it must be a fair sample of the body, but in favourable

circumstances it is easy to get three or four hydrae from one. Not only can the hydra regrow a lost tentacle: it can regrow the whole from a part. This power, technically called **regeneration,** becomes less and less among the higher animals and we shall explain afterwards why this should be so.

Hydra is so simple and has such powers of repairing injuries that we cannot but ask whether it does not resemble the amoeba in being exempt from natural death. The answer seems to be in the negative, for in spite of all possible care it has not been found possible to keep an individual hydra alive for more than two or three years.

Hydra has some interesting relatives: *Protohydra,* without tentacles; *Microhydra,* also without tentacles, very interesting because it buds off and liberates minute swimming-bells (see INDEX). Three other freshwater swimming-bells or medusoids are known, which are probably budded off and set adrift from hydra-like forms. A strange simple polyp, called *Polypodium,* occurs as a parasite on the eggs of the sturgeon!

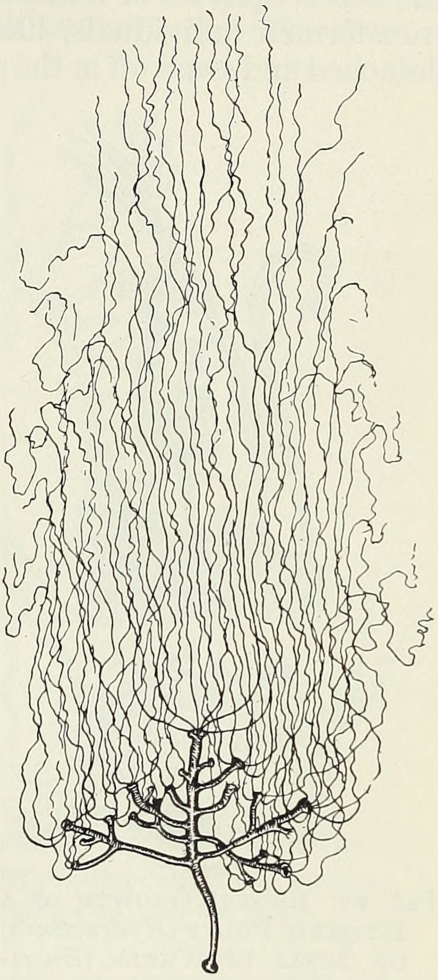


FIG. 28. A MUCH-BRANCHED HYDRA, AS FIGURED BY THE ABBÉ TREMBLEY, 1750

ZOÖPHYTES AND SWIMMING-BELLS (HYDROIDS AND MEDUSOIDS).—The freshwater Hydra sometimes produces buds which produce buds. If this repeated budding were continued a hundredfold, the result would be an animal colony, and such is a **zoöphyte,** like a 'sea-fir' or a 'sea-brush.' As such a colony grows, often in tree-like fashion, it has to be supported by a non-living external skeleton (the **perisarc**) which often forms special cups (*hydrothecae*) for the hydra-like individuals or polyps, and special cups (*gonothecae*) for the reproductive members of the colony. There is often some division of labour, for besides nutritive and reproductive members there may be very sensitive individuals, and so forth. The little *Hydractinia,* that grows as a pinkish encrustation on the shells that hermit-crabs have borrowed, shows in its colony four different kinds of individuals all sharing a common life. It is understood, then, that a zoöphyte, to the naked eye more like a plant than an animal, which may be

tossed up among the jetsam on the seashore, is not a single animal, but a united *colony* of hydra-like animals, often showing division of labour, and supported by a flexible external skeleton.

The next step is more difficult. Many of the zoöphytes, such as the bell zoöphytes or *Campanularians*, produce in the summer months transformed individuals, like minute transparent bells, which become detached and swim off in the sea. These are the swimming-bells or medusoids, often about the size of a currant or a gooseberry, delicate transparent animals suited for the Open Sea. They produce eggs or sperms, and from the fertilized eggs there develop free-swimming ciliated ovals or the like. These eventually settle down and develop into polyps, which by budding make the zoöphytes we began with.

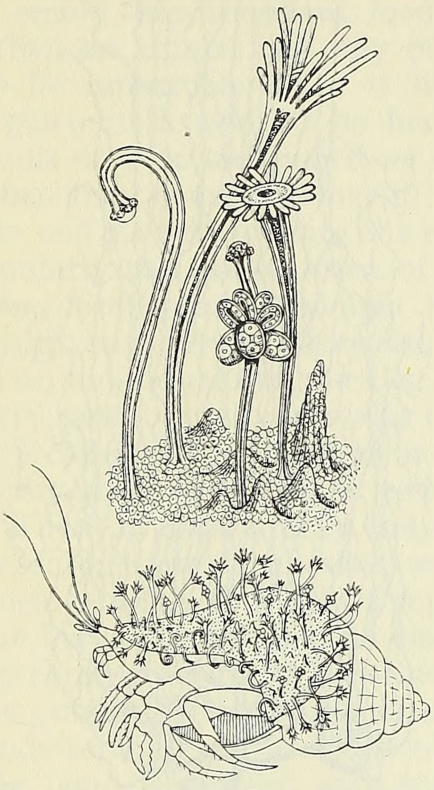


Fig. 29. Epizoic Growth of a Hydroid Polyp (*Hydractinia*) on Shell of Whelk (*Buccinum*) Tenanted by a Hermit-crab. Above, Portion of Lower Figure Enlarged.

This strange see-saw is called **alternation of generations:** an asexual fixed zoöphyte buds off a sexual locomotor swimming-bell, whose fertilized eggs develop into zoöphytes again. The definition may be written in separate lines:

The alternate occurrence in one life-history
(for the zoöphyte and the swimming-bell are just two chapters)
of two or more different forms
(for what could be more different than the fixed zoöphyte and the free swimming-bell?)
differently produced
(for the swimming-bell is produced asexually and the zoöphyte sexually).

Two advantages of the medusoids are that cross-fertilization is made almost certain, and that there is a chance of the new zoöphytes starting life in a less crowded area. In other words, the swimming-bells secure the scattering of the zoöphytes.

Other instances of Alternation of Generations. The alternation takes many forms, but it is well illustrated by the common jelly-fish, by the liver-fluke and its relatives, by many insects which have alternate asexual and sexual generations, and by some of the sea-squirts. It is common in the plant world, and is very clear among Ferns and Mosses. Let us take the usual fern story. A

leafy and often stately asexual 'fern plant' produces spores, usually on the under-surface of the fronds, and when these spores are scattered and sink into the ground, each develops into a minute green platelet, the inconspicuous prothallus, which has male and female organs. From a fertilized egg-cell in the prothallus there develops the large spore-making fern plant. This also is alternation of generations.

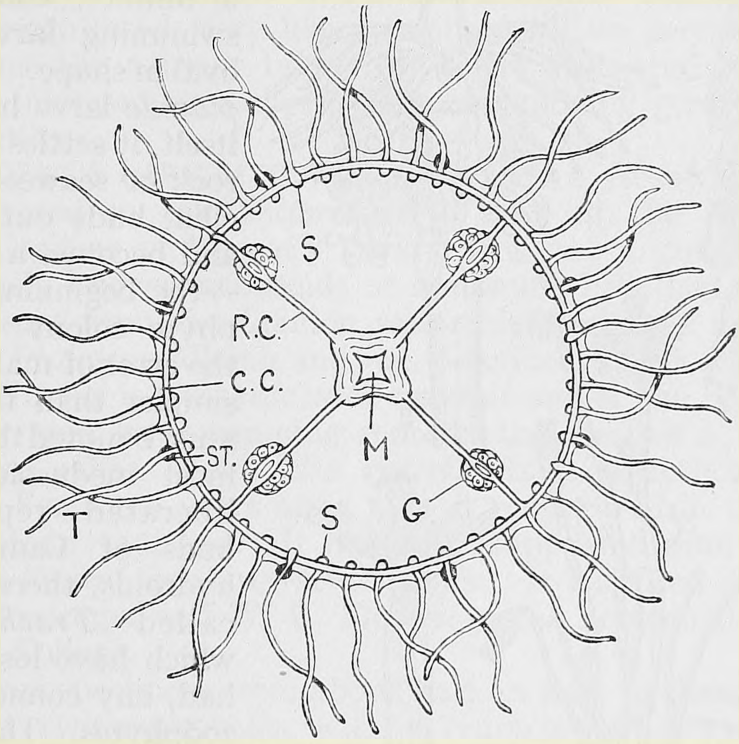


FIG. 30. A SWIMMING-BELL

G, gonad or reproductive organ; M, mouth; RC, radial canal; CC, circumference canal; S, sense-organ; ST, stinging-cell; T, tentacle.

SKETCH OF A SWIMMING-BELL.—Picture a currant-sized transparent bell, pulsating in the water. In the centre, where the 'clapper' of the bell should be, there hangs the mouth. It leads into a tiny stomach in the dome, from which four or more radial canals extend to the margin, there to be united in a circumference canal. Around the margin there are several tentacles, with many stinging-cells; there are usually sense-organs at the base of the tentacles—either light-perceiving or balancing; these are connected by a nerve-ring, for the medusoid is making progress compared with a hydra, which had only a loose network of nerve-cells. Around the margin of the bell there is a delicate inward-projecting shelf, called the *velum*. When the curvature of the bell is altered by contracting the muscle-cells of the outer layer, the water is driven out, and this propels the

animal in a very beautiful way. The living bell pulsates or throbs, but the resulting locomotion is not rapid. The sexes are usually separate and the reproductive organs can be seen with the naked eye as thickenings on the clapper of the bell or on the sides of the radial canals. The fertilized egg develops into a minute, ciliated, free-swimming larva, usually oval in shape. When this *planula* larva has fatigued itself, it settles down on a rock or seaweed, loses its cilia, buds out tentacles, and becomes a tiny polyp —the beginning of a zoöphyte colony. To avoid the error of making things simpler than they are, it must be noted that whereas most medusoids are the liberated reproductive buds of Campanularian hydroids, there are some, called *Trachymedusae*, which have lost, or never had, any connection with zoöphytes. They give rise more or less directly to swimming-bells like themselves.

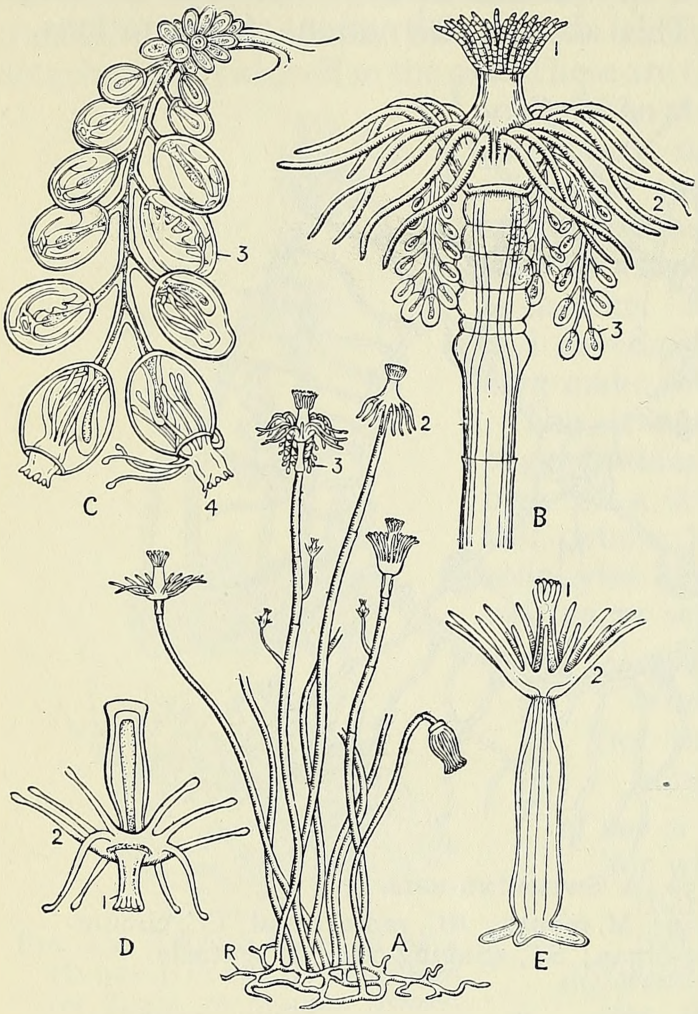


FIG. 31. LIFE-HISTORY OF *Tubularia*

A, zoöphyte colony; B, single polyp enlarged; C, gonophores (sexual organs) enlarged; D and E, stages in the growth of the larva ('actinula larva'); 1, oral tentacles; 2, aboral tentacles; 3, gonophores; 4, actinula larva.

Another complication is that many of the zoöphytes do not go the length of liberating free-swimming medusoid buds, and yet have them in more or less rudimentary or disguised form. Thus the common *Tubularia larynx* has somewhat medusoid-like reproductive buds which are not set adrift, whereas its not very distant relative *Bougainvillea ramosa* liberates the medusoid called *Margelis ramosa*. The difference in the name shows that both forms were known before it was discovered that they represented two chapters in the life-history of one animal. A very common zoöphyte called *Obelia geniculata* liberates a small medusoid which goes by the same name, and this is

what may be called typical. Some of the hydroid colonies have become very much embedded in limestone, just like corals, and it is striking to find that some of these *Millepores*, as they are called, liberate free-swimming medusoids. It is as if a rock gave birth to a fish! The Millepores show that ' corals ' may be formed by zoöphytes, but this must not obscure the big fact that the ordinary zoöphyte is a flexible colony, sometimes tree-like, sometimes branch-like—never, it must be confessed, very like an animal till we peer into it with a lens and see the cups or tubes; or, better still, study a piece alive under the microscope, with the tentacles moving gently around the many mouths.

THE REGENT'S PARK MEDUSOID.—In 1880 a freshwater medusoid was discovered in the *Victoria regia* tank at the Royal Botanic Society's Gardens in Regent's Park. This was a great surprise, for all previously known medusoids or swimming-bells had been marine. The medusoid from the London water-lily tank was named *Limnocodium* by Professor Allman and was described by Sir Ray Lankester. Its present name is *Craspedacusta sowerbii* and it has been proved to be the liberated free-swimming reproductive bud of a simple freshwater polyp called *Microhydra ryderi*, which is at home in North America. For some years after 1880 it reappeared in the water-lily tank, and then vanished. It has now reappeared after an interval, so far as is known, of thirty-seven years. It has been studied afresh by C. L. Boulenger and W. U. Flower, of the Zoological Department of Bedford College.

The largest specimens were about half an inch in diameter, dainty, transparent swimming-bells, with a tentacle for every day of the year bar one, and with 160 marginal sense-organs. They often spend much of their time at the bottom of the aquarium, feeding on unicellular organisms; but at intervals they propel themselves upwards by pulsating their bell. At the surface they relax into flattened disks, and then sink downwards again with the mouth or clapper of the bell protruded so as to catch small crustaceans and the like.

The freshwater medusoid has been found in the *Victoria regia* tanks of Botanic Gardens at Sheffield, Birmingham, Lyons, and Munich. It has been recorded from various parts of the United States; a closely related form occurs in China, and what seems to be a distinct species is known from Japan. All the Regent's Park specimens were males, and this has been noticed by all other observers, except Payne, who found that those he obtained from a lake in Indiana were all females. It is suggested that the polyp stage, not seen at Regent's Park, may be *dioecious*, that is to say, able to produce only one sex of medusoids; and that a single introduced polyp, multiplying asexually, starts the whole colony in the tank. ' Its asexual offspring are naturally capable

of budding off only medusae of the same sex as the parent form.' In any case, it is now certain that we have here to do with *alternation of generations* (see p. 88). The simple fixed non-sexual polyp, *Microhydra ryderi*, buds off the elegant free-swimming sexual medusoid, *Craspedacusta sowerbii*, whose ova, if fertilized, should develop into polyps. The probability is that the fixed polypoid stage is a secondary interpolation into the life-cycle, which was primarily free-swimming from first to last; but some zoologists read the facts the other way round, regarding the hydroid stage as primary.

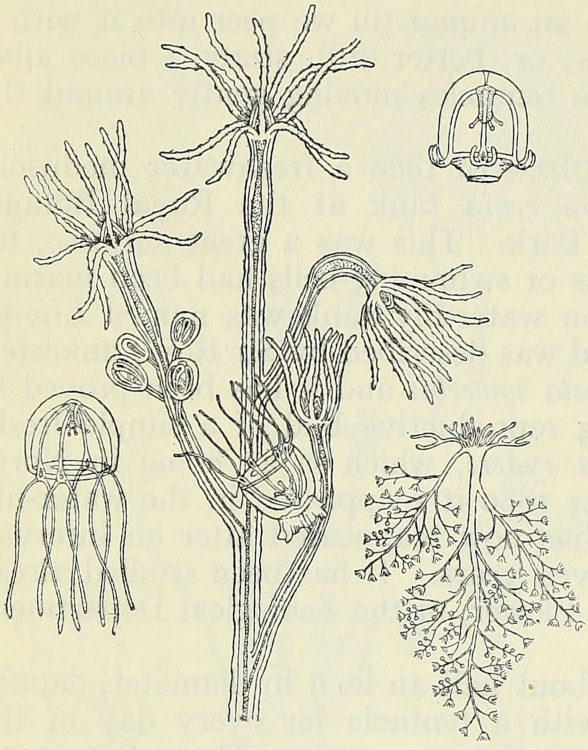


FIG. 32. THE ZOÖPHYTE COLONY *Bougainvillea*, AND FREE-SWIMMING MEDUSOIDS

It seems a pity to speak of the animal in question as a 'jellyfish,' and we venture to suggest that true jellyfishes be always called *medusae*, while the not nearly related swimming-bells be always called *medusoids*. The resemblance is purely superficial and adaptive.

PORTUGUESE MAN-OF-WAR.—This quaint name is given to a brightly coloured free-swimming colony of what may be called transformed swimming-bells. It occurs in warm seas all over the world, and gives one a first impression of a huge swollen and livid (blue and red) cockscomb projecting on the surface. What projects is a bladder or buoy full of gas, and sometimes four inches long. It is said to arise by the enormous expansion of a single member of the colony. Below the bladder there are numerous individuals, some nutritive, some reproductive, some tactile, some very rich in stinging-cells. The Portuguese man-of-war is a virulent stinger, and can actually capture a mackerel. Only male colonies have been found, a curious fact which suggests that the females must have a quite different appearance. It is interesting to find a colony with many members, which can nevertheless move in the water as if it were one animal. When a complex whole is bound into unity, so that all the parts act in harmony, the result is called **integration**—a difficult, but very important word. Mere complexity of parts is called **differentiation**. A modern motor car shows *both*; it is very intricate, with much division of

labour (differentiation), but it is also very thoroughly unified and thus under control (integration).

On to British coasts there is sometimes drifted from the Atlantic a beautiful blue colony, about the size of a five-shilling piece. It is called *Velella*, which means 'little sail,' for there is a delicate, translucent, vertical, triangular crest rising from the upper surface of the disk, while numerous individuals of various kinds hang down below. On the Mediterranean one sometimes sees little fleets of Velella (Sallee-rover) floating on the surface—a very beautiful sight. It is interesting to note that the larva of this blue surface swimmer lives in deep water (even at five hundred fathoms) and is red in colour. The Portuguese man-of-war and Velella have many relatives, which form an order called **Siphonophores.** They are interesting in many ways: in being free-swimming colonies; in showing much division of labour; in sometimes acting like one animal; and in being in adult life characteristically Open-Sea or **pelagic** creatures. They are perhaps the worst stingers among the stinging animals, and the poisonous lassos sometimes reach the huge length of a fifth of an inch!

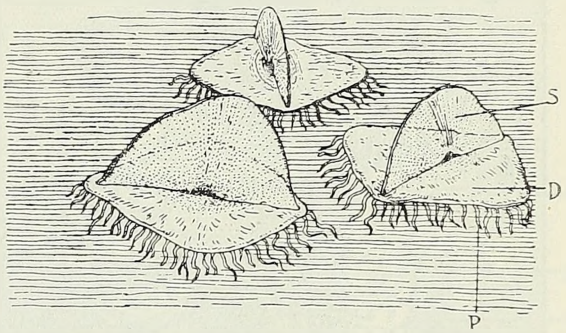


FIG. 33. THE SALLEE-ROVER (*Velella*), FLOATING ON THE SEA

D, disk; P, polyp; S, crest.

In some ancient rocks, Silurian in particular, there are common fossils called **Graptolites,** often very dainty, with numerous minute cups arranged on an axis. What they really were is uncertain, but there is considerable probability that the parts preserved belonged to free-swimming Coelentera, possibly related to the Siphonophores.

JELLYFISHES OR MEDUSAE. — With a superficial likeness to swimming-bells or medusoids are the true jellyfishes or medusae. A good example is the common *Aurelia aurita*, abundant in most seas. It is usually of a milky-blue colour, but varies not a little. Those seen round British coasts or stranded on flat beaches are oftenest about the size of a soup-plate, but there are monsters of the same species with disks big enough for a mermaid to sit on. A diameter of two feet has been recorded from the Malay Archipelago. Great shoals are sometimes seen together, drifting along or swimming gently with rhythmic changes in the curvature of the disk by which water is driven out. The food of jellyfishes consists of Open-Sea animals, such as crustaceans and fishes, which are entangled and stung to death by the long lips. Under the shelter of the umbrella of some of the jellyfishes there are sometimes true fishes, such as young whiting

in the case of *Cyanea*. A hundred young horse-mackerels may shelter under the jellyfish *Rhizostoma*, which does them no harm; and they will even take refuge in small pouches on the under-surface of the disk. The association is not well understood, and it seems to occur in various degrees in different kinds. For it sometimes happens that the guests will nibble at the jellyfish, or the host engulf the little fishes. The stings of the common Aurelia can hardly pierce the human skin, but the larger orange-coloured and blue Cyaneas are to be avoided. They are sometimes more than troublesome to bathers and swimmers. Some of the Cyaneas must be the largest of backboneless animals, for there is a record of one with a disk diameter of $7\frac{1}{2}$ ft. and tentacles 120 ft. long. These tentacles trailing behind the animal might readily give a credulous eye the impression of a **sea-serpent.** Other 'sea-serpents' may have been giant cuttle-fishes, large sharks, oar-fishes, dolphins, or porpoises swimming in a line.

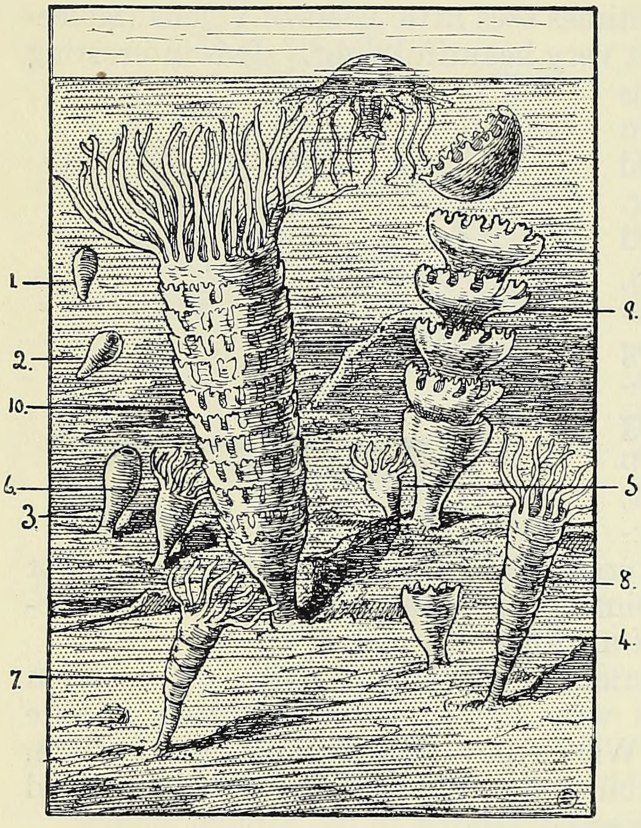


FIG. 34. DIAGRAM OF LIFE-HISTORY OF *Aurelia*

1, 2, various stages of free-swimming embryo; 3–6, stages of hydra-tuba, p. 96; 7–10, liberation of ephyrae, p. 96.

Structure. — A common jellyfish (*Aurelia*), floating freely, shows a disk convex above like an inverted saucer. Shining through the transparent skin and the watery middle-jelly (*mesogloea*, p. 72) there are four brightly coloured reproductive organs and numerous canals leading from the central stomach to the circumference canal. Round the margin there are numerous short tentacles. If the animal is turned upside down on the sand, the mouth is seen in the centre with four long much-frilled lips. In eight notches at regular intervals around the circumference there are sense-organs, each triple. These are sensitive to light and to chemicals, and they also help in balancing. They are connected by a network of nerve-cells spread over the under-surface of the disk or umbrella. On a dead jellyfish

floated in a milk-basin it is not difficult to find four open pockets just below the reproductive organs. Another feature is the presence of ring-like bundles of cross-striped muscle-fibres on the under-surface of the disk, lying between the nerve-cell network and the middle-jelly of the lower half of the disk. These muscle-fibres alter the shape of the disk when they contract and relax; and it is thus that the jelly-fish swims. In the tentacles and lips there are unstriped muscle-fibres, which contract more slowly than those that are striped. But this must be explained a little.

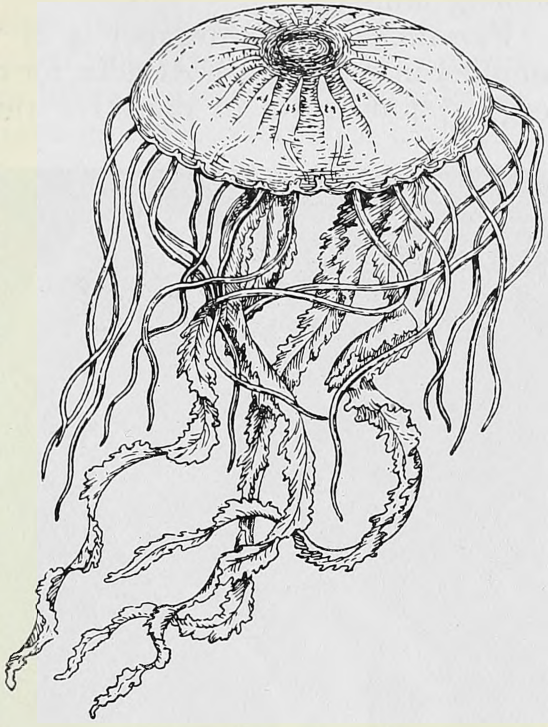


FIG. 35. A COMMON JELLYFISH

What is ordinarily called a piece of flesh is a piece of **muscle.** It is made up of many contractile threads or fibres, usually coloured red because of the blood that supplies them, but in many animals they are practically transparent, as in the jellyfish. A muscle-fibre is usually an elongated single cell, but sometimes several muscle-cells join together to make a long fibre. When muscle-fibres are examined under the microscope, it is found that some of them show very numerous close-set transverse lines, while others are uniform throughout their length. The cross-striated fibres form what is called **striped muscle,** the others **smooth** or **unstriped muscle**; and the general fact to be kept in mind is that the striped contract much more rapidly than the smooth. Thus we find that in very active animals, like insects, almost all the muscles are striped, while in sluggish animals, like sea-squirts, the muscles are chiefly unstriped. In the same way, slowly moving structures, like a stomach, have unstriped muscle, while quickly moving structures, like limbs, are worked by striped muscle. Perhaps it should be noticed that the striped muscle-cell of a jellyfish is not nearly at the level seen, for instance, in the crustaceans that the jellyfish catches. For in the jellyfish muscle-fibre or muscle-cell there is a large part still non-contractile, whereas in a higher animal

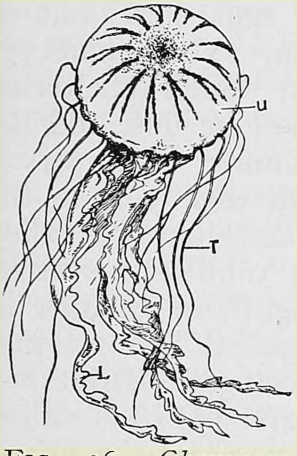


FIG. 36. *Chrysaora*, ANOTHER JELLYFISH
L, labial tentacle; T, tentacle; U, umbrella.

the whole of the muscle-cell has become contractile. This is useful as an instance of the gradual way in which progress has been made among animals.

Variations.—The number 4 is what might be called the ruling number in the jellyfish *Aurelia*, for there are four lips, four reproductive organs, four tufts of digestive threads ('gastric filaments') in the stomach, eight sense-organs, eight branched and eight unbranched radial canals radiating from the central stomach to the circumference, and so forth. But it often happens in a jellyfish that three, or four, or six is the number of the parts that are normally four; and this is what is called a **variation,** an inborn novelty that makes the offspring different from its parent. There has been some disturbance of what is usual, just as in a white blackbird or a cat with no tail.

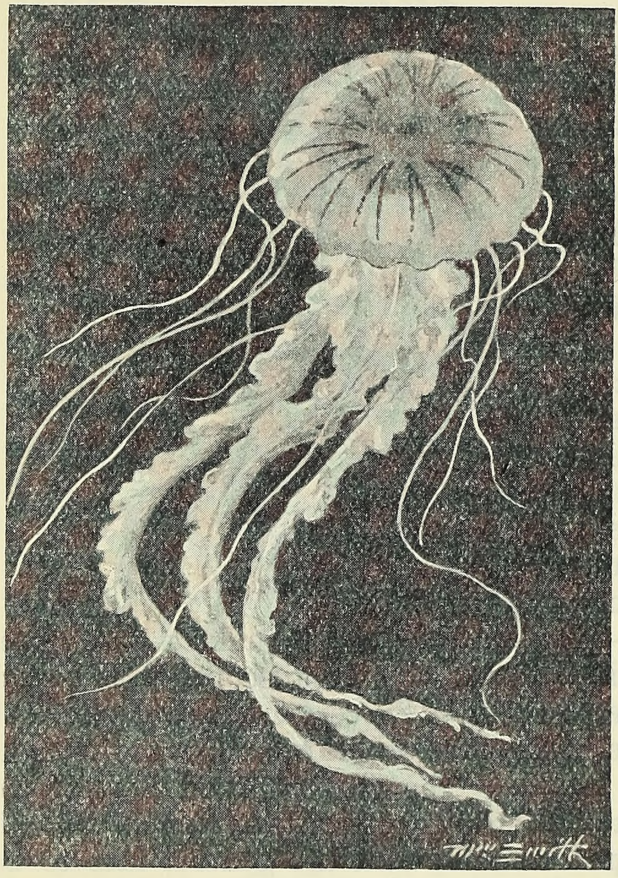


Fig. 37. A Jellyfish Swimming in the Sea

Life-history. — The sexes are separate in *Aurelia*, as in most jellyfishes, and the fertilized eggs come out at the mouth. Young embryos are often found sheltering about the long lips, and the free-swimming oval larvae swim with their cilia in the sea. Soon, however, they settle down on a stone or a seaweed, as little tubular creatures, called 'hydra-tubae' (see Fig. 34), about an eighth of an inch in height. The hydra-tuba develops tentacles, a gullet, and internal partitions, and as it grows larger it shows a number of constrictions, so that it is often compared to a pile of saucers. This is called the *strobila* stage. The little disks tumble off, one after the other, and, turning upside down, swim away as 'ephyrae' (see Fig. 34), which grow into jellyfishes. So there is *alternation of generations* (p. 88) again: the sexually-produced hydra-tuba buds off little jellyfishes, with the pile-of-saucers stage intervening. The sequence is: Jellyfish, fertilized egg, embryo, free larva, fixed asexual hydra-

tuba, *strobila* or pile-of-saucers, liberated disk or *ephyra*, young jellyfish. In some cases, such as *Pelagia*, there is no fixed stage: jellyfish gives rise to jellyfish.

It must be clearly understood that jellyfishes or *Medusae* have nothing to do with swimming-bells or medusoids (see p. 92). Most medusoids are much smaller and most are liberated from hydroid colonies. Many medusae are large and they have no connection with hydroids. The two kinds of animal are very different in internal structure; they are like one another only in being similarly adapted to swimming and drifting in the Open Sea. This kind of superficial resemblance is called **convergence.**

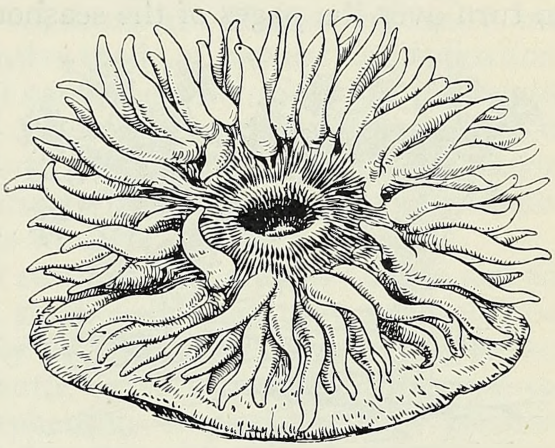


Fig. 38. The 'Dahlia' Sea-anemone (*Tealia felina* or *crassicornis*)

Sea-anemones and their relatives.—The hydras and the zoöphytes may be called the *lower* polyps, while sea-anemones and their relatives are the *higher* polyps, forming a class called *Anthozoa*. Sea-anemones are fixed tubular animals with a crown of stinging tentacles round the mouth, but they are much more complicated than the Hydrozoön polyps. Notably they have the outer layer turned in to make a **gullet,** and the food-cavity is divided by upright partitions (or *mesenteries*) into a number of compartments, all in communication. These partitions usually bear digestive threads, just like those that are found in true jellyfishes; and this gives us a hint, which other resemblances (such as the gullet) confirm, that the relationships of the sea-anemones are with the jellyfishes. Lower polyps and medusoids go together; higher polyps and medusae go together. There is a strong resemblance between a young sea-anemone and the young fixed stage (the hydra-tuba) in the life-history of the common jellyfish. Here it may be noted that a few of the jellyfishes, called *Lucernarians*, are actually sedentary forms after their earliest youth is past. This brings the two classes closer still.

Sea-anemones are often beautifully coloured and nestle like flowers in the niches of the rocks, with the numerous tentacles dangling in the water and capturing booty. The food consists of small animals such as crustaceans and worms; and a few have helpers in the form of partner-algae (see SYMBIOSIS) in their inner-layer cells. Though a typical sea-anemone is fastened by its base to rock or shell or seaweed, they are all able to shift their position a little, and some are only loosely embedded in the sand. Some reef-anemones turn

upside down and creep about by means of their tentacles, like very sluggish medusae.

In the summer holidays, when many of us visit the seashore, we ought to give a little study to the sea-anemones, with their attractive shapes, colours and habits. We cannot be expected to take with us Dr. Stephenson's beautiful monograph, but there are admirable guides to the Natural History of the Seashore by Newbigin, Elmhirst Sinel, Boulenger, Pycraft, and others. One of these guides will make our holiday ever so much more interesting, and it seems a pity not to turn over the pages of the seashore book itself.

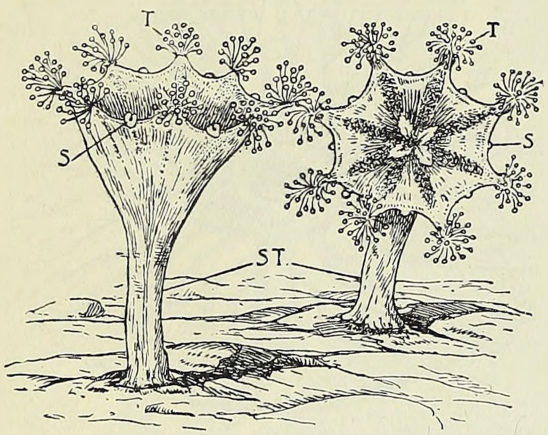


FIG. 39. ONE OF THE *Lucernaridae* (*Haliclystus auricula*)

S, marginal anchor; ST, stalk; T, tentacle.

A good beginning may be made with the sea-anemones that we have just spoken of, for they cannot run away as most creatures do, though many of them can move a little from place to place. There are forty different kinds on the British list, but we shall have done not so badly if we make the acquaintance of six in our first summer. Thus there is the common *Actinia equina* or *Mesembryanthemum*, very variable in its colouring, oftenest a lovely red with a circlet of turquoise beads around the base of its tentacles. The beads are like blue eyes, but they are simply batteries of stinging-cells! This sea-anemone does not sting an ordinary human finger, but, as mentioned on p. 82, if you kneel down and push your tongue into the midst of the tentacles you will find that the textbooks are sometimes right. If the experiment suggested be objected to, you can at least notice that the tentacles adhere gently to your little finger, and that is because the ejected poisonous lassos are clinging to the skin, which they are not strong enough to pierce.

Also very common is the thick-horned sea-anemone, the rough-skinned variety of *Tealia felina* (Fig. 38), which used to be called *Tealia crassicornis*, a large squat form with short, very thick white-banded tentacles. The surface of the body is covered with warts, to which fragments of shells are often attached. The common colours are reds and greens, and the floor of a little cave or a deep gully is often covered with individuals the size of a breakfast cup and without the extraneous covering that half conceals those that live in opener places. This Tealia feeds somewhat voraciously on small crabs, which are grappled and paralysed by the tentacles and then pushed into the mouth.

A large immediately recognizable species, often seen on the supports of piers on the west coast, is the plumose anemone, the *dianthus* variety of *Metridium senile*, which Gosse called *Actinoloba dianthus*. Its column is sometimes six inches high, and the broad disk is surrounded by puckered lobes bearing very numerous small tentacles. The colour varies from pale reddish, through salmon, to white; and the display on some of the piers is gorgeous beyond description. This is one of the sea-anemones that shift about not a little, sometimes leaving behind it on the old site a fragment that can regrow the whole. On occasion the entire sea-anemone divides vertically into two, thus illustrating a very expensive mode of asexual multiplication.

Also very common is the small cave-anemone (*Sagartia troglodytes*) that lives in sheltered holes and crevices, often among mussels. Its beautifully marked tentacles radiate around the disk like the narrow florets of some Composite,[1] presenting a somewhat stellate appearance. When our eye catches sight of one we soon see half a dozen.

Sea-anemones will capture and swallow any animal that is not too large for them—from worms to small fish; and the usual methods are to seize and paralyse the booty by means of the tentacles, to waft it by means of cilia into the mouth, or to grip it by means of the mouth and gullet. As Dr. Stephenson emphasizes, the anemone does not close up after feeding, unless it be for a short time until the victim has ceased to move. After that it is the normal thing for the polyp to expand to its widest.

Sea-anemones seem to experiment fairly widely with different modes of multiplication; for some of them liberate eggs which are fertilized in the water, while in others the development goes on within the parent, and miniature anemones pass out of the mouth. The troglodyte shows both methods. Longitudinal splitting is not uncommon; transverse splitting is occasional. Moreover, a small basal fragment may be constricted off and move away on its own or may be torn off and left behind when the parent, if it be worthy of the name, shifts its quarters.

Sea-anemones have many enemies, such as certain fishes, sea-slugs, and sea-spiders; but they hold their own with marked success, and may attain to great longevity. Some have been kept in an aquarium for over three-score years and ten, and Dr. Stephenson thinks that they may survive for hundreds of years in suitable natural conditions. They feed easily and well; they are abundantly equipped with stinging-cells; and they do not worry. In fact, we must not credit them with more than the beginnings of a nervous system—a network of nerve-cells without any centralization. If the tentacles on one side of the mouth learn to refuse faked food, such as blotting-paper dipped in

[1] Plant of the daisy family, *Compositae*.

beef-juice, those on the other side are none the wiser, and may be repeatedly duped. Each half of a sea-anemone has to learn its own lessons. In connection with sea-anemones should be noted a kind of partnership that hermit-crabs may establish with some of them which they carry about. The hermit-crab is masked by the sea-anemone or sea-anemones (for there may be as many as four), and it may be protected by their stinging powers. The sea-anemone is carried about by the hermit-crab, and may get crumbs from its abundantly supplied table. This is an external mutually beneficial partnership, and is called **commensalism.** As we have explained, an *internal* mutually beneficial partnership, such as that between a sea-anemone (e.g. *Anemonia sulcata*) and one-celled green algae, is called **symbiosis.** A one-sided association when one creature gets food and shelter at the expense of another, and does not fend for itself, is called **parasitism.**

INCIPIENT COMMENSALISM.—Most of the cases of commensalism, such as that between hermit-crabs and their sea-anemones, are apparently of long standing. They work smoothly, and the partnering tendency seems to be ingrained, as we see when the sea-anemone takes the initiative in clambering on to the hermit-crab, or when the crustacean evidently searches for a partner that has been experimentally removed. The mutualism is often subtle, and one is puzzled to account for its evolution at a low level of intelligence. This difficulty gives particular interest, we think, to some recent observations by Mr. David Landsborough Thomson on an *incipient* association between a spider-crab and a sea-anemone. In the aquarium of the Zoological Station at Roscoff in Brittany fifteen individuals of the spider-crab *Stenorhynchus phalangium* showed more or less of a habitual association with the sea-anemone known as *Anemonia sulcata* or *Anthea cereus*, which does not draw in its tentacles as most of its relatives do. The crab shelters among the drooping tentacles, and is to some extent hidden by them. Sometimes it climbs up to near the anemone's mouth or snuggles half under the base. The anemone does not resent these familiarities, but if the crab happens to die, its body is soon lifted up and devoured. When the experiment is made of dropping a scrap of flesh into a basin containing the two animals, the crab soon finds it, and retreats to its shelter. But the booty is quickly caught by one of the sea-anemone's tentacles, and the crab is seen to search about in the neighbourhood for what has been snatched from its very lips. A day or two later the undigested remnants of the meal are rejected by the anemone, and if they are found by the crab, they are devoured. It may be frequently observed when the crab is in its usual sheltering position, that a single tentacle from the Anthea hangs loosely down over the crab's beak, just as if on the outlook. The case appears extraordinarily like incipient com-

mensalism; the sea-anemone gets food and the crab gets shelter. There is no reason why we should suppose that evolution is not going on.

REEF-CORALS AND THEIR RELATIVES.—A sea-anemone is a single animal, and there are nearly related **solitary corals.** Thus there is a small British cup-coral called *Caryophyllia*. A coral of this type is simply a sea-anemone-like animal with a hard shell of limestone which is laid down by cells of the soft outer layer. A disk of limestone is formed between the coral polyp and the surface of the rock or stone. On this disk as foundation, ridges of limestone begin to rise, and these grow into vertical partitions, the soft flesh of the polyp retreating before them as they rise. The outer edges of the partitions or septa become united in an external wall, and sometimes there is a pillar of limestone in the very centre. Some of these solitary corals are very beautiful, but it must be understood that when the polyp is alive it hides all the shell or skeleton. It looks as if the animal was outside the shell, but in reality the shell is outside the animal!

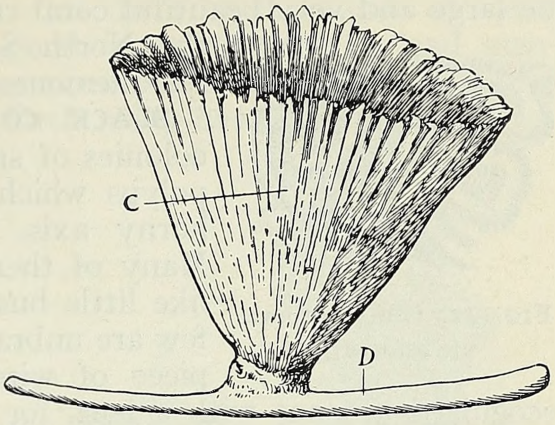


FIG. 40. SOLITARY CORAL, ON *Dentalium*
C, coral; D, *Dentalium*.

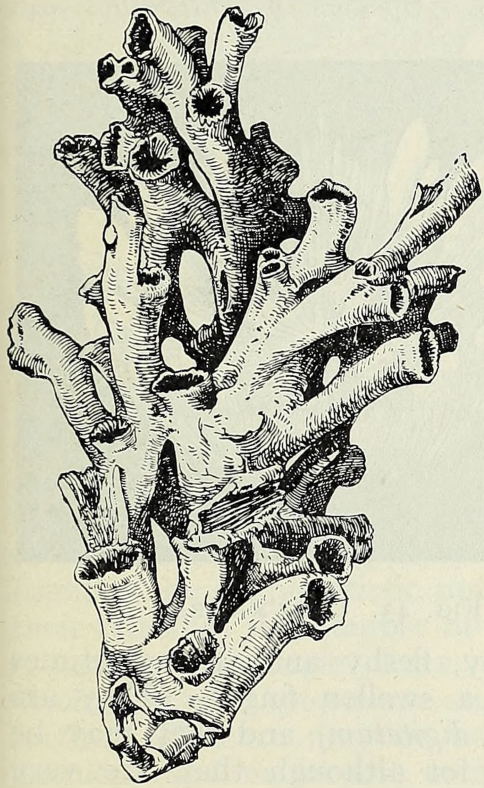


FIG. 41. NORTH SEA CORAL

Sea-anemones and cup-corals are single animals, but the great masses that form coral reefs are vast **colonies of polyps.** They arise by budding or by division, and the individuals often become so crowded that it is impossible to tell where one ends and the next begins. As the individuals multiply and crowd on one another, the older ones die away and the younger ones rise on their shoulders. Thus in a big mass of coral on a coral reef, the living polyps are confined to the surface; below that there is 'coral rock.' The substantial reef-building corals are mostly confined to a belt extending 30° on each side of the equator, and it is rare for living reef-corals

to be found below the forty-fathom line. But there are many relatives of reef-corals that are not subject to these restrictions. Thus the large and very beautiful coral called *Lophohelia* is often found in the North Sea. All these corals related to sea-anemones are called **Madrepores.**

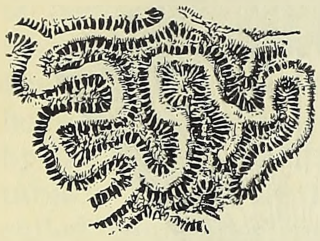


FIG. 42. BRAIN-CORAL (*Coeloria*)

BLACK CORALS.—These are very strange colonies of small, somewhat sea-anemone-like polyps which form and grow round a hard horny axis, sometimes as black as ebony. Many of them are like bottle-brushes, others like little bushes, some are like plumes, and a few are unbranched with an axis like a twisted piece of wire. Even a little piece can be recognized at once with a lens, for the axis is covered with minute triangular spines like rose prickles. There is no trace of limestone in these black corals or **Antipatharians.** All but one kind have six simple tentacles that cannot be drawn in. The exceptional form, called *Dendrobrachia*, has eight feathery retractile tentacles, and seems to link on to the sea-fans (see INDEX). Species of *Antipathes* and two or three other kinds have been dredged in the North Sea and off the west coast of Ireland. It seems strange to put in the vicinity of sea-anemones these tree-like, plume-like, or whip-like colonies, sometimes a couple of feet high, with many hundreds of polyps, but the reason is simply that there is considerable resemblance in the structure of the polyps in the two orders.

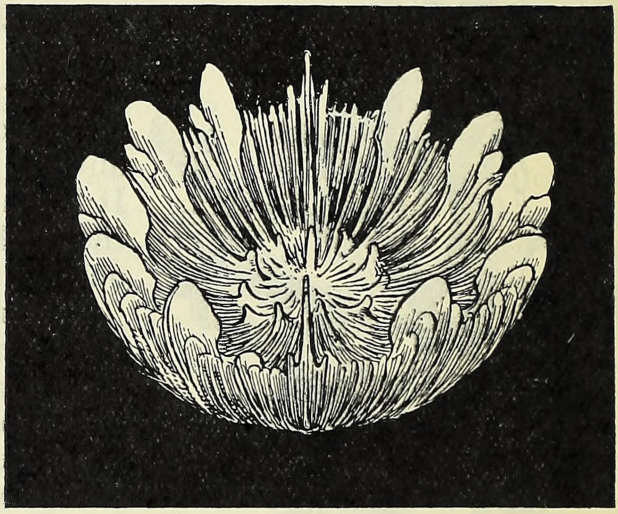


FIG. 43. CROWN-CORAL

RED CORALS AND THEIR RELATIVES.—On many shores after a storm one may find on the flat beach a number of flabby, fleshy animals, sometimes like a swollen hand, sometimes like a swollen finger. They are called dead men's fingers (*Alcyonium digitatum*) and they may be thought of as corals in the making; for although they are very soft when freshly thrown up among the jetsam, they are riddled with minute spicules of limestone. On the surface of a dry piece there are numerous little holes, the openings through which the polyps protruded; and if a stout branch be cut across with a knife,

numerous canals may be seen communicating with the food-canals of the polyps and with one another. In between the canals there is 'middle-jelly' (mesogloea) and in this there lie thousands of microscopic spicules. If one has the good fortune to see a dead men's fingers colony flourishing in an aquarium with the polyps expanded, one sees a very beautiful sight. Each polyp has eight feathered ten-

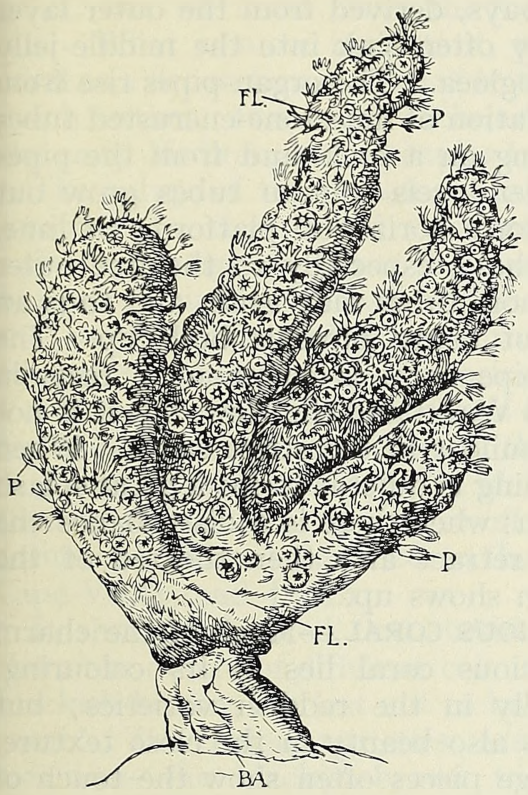


FIG. 44. DEAD MEN'S FINGERS
(*Alcyonium digitatum*)
BA, base; P, polyp; FL, fleshy growth.

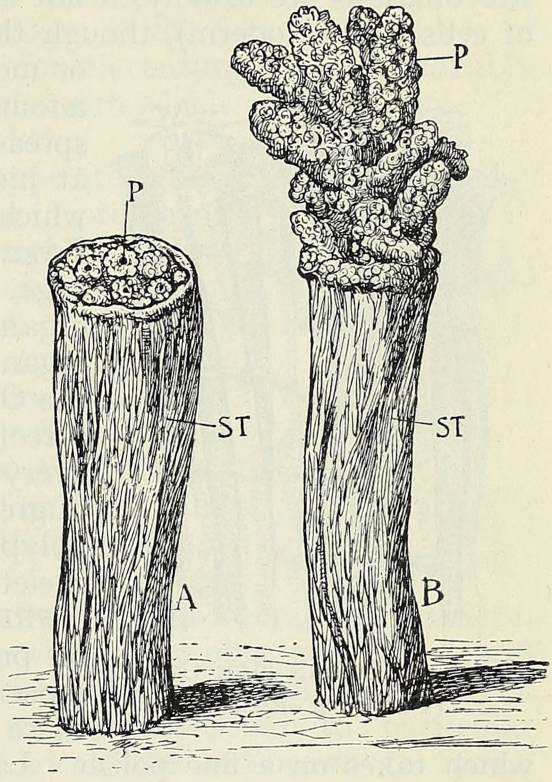


FIG. 45. ALCYONARIAN CORAL
A, contracted; B, expanded; P, polyp; ST, stalk.

tacles around the mouth, and there are eight vertical partitions (or mesenteries) extending from the in-turned gullet to the body-wall. Eight is the characteristic number, whereas in the sea-anemones and their relatives the number of tentacles and mesenteries and so forth is usually a multiple of six. Thus there is a contrast between the *Octocoralla* or *Alcyonarians* and *Hexacoralla* or *Zoantharians*, and this further difference may be noticed that, whereas many of the sea-anemone and madrepore coral group are single individuals, all the members of the dead men's fingers group are colonies, except two or three.

The organ-pipe coral (*Tubipora musica*) is one of these **Alcyonarians**, and a beautiful colony it is, a group of red tubes bound together cross-

wise at intervals. Each pipe contains a polyp whose eight green feathery tentacles protrude at the mouth. As the polyp grows longer it adds to the rim of its tube, for minute red spicules of limestone are fitted on in some mysterious way as if they melted and immediately solidified again. We may mention here that the beautiful and very varied spicules of limestone that are characteristic of the Alcyonarians are usually, if not always, derived from the outer layer of cells (the ectoderm), though they often sink into the middle-jelly or mesogloea. The organ-pipes rise from a foundation of limestone-encrusted tubes spreading on a rock, and from the pipes at higher levels minute tubes grow out which form horizontal platforms of lime. From these, especially to the free outer edge, more tubes may arise, and thus an organ of many pipes is built up. The organ-pipe coral is common on reefs in the Old World and the New, but it is not a reef-builder in the strict sense. When everything is quiet it forms a great splash of green; when there is a disturbance the polyps retract and then the red of the skeleton shows up.

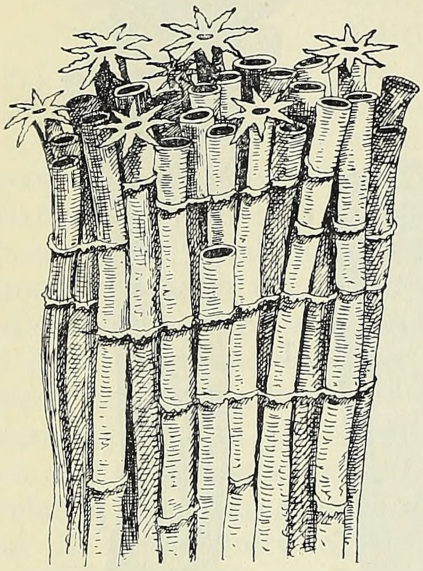


Fig. 46. Organ-pipe Coral (*Tubipora musica*)

PRECIOUS CORAL.—Much of the charm of precious coral lies in its colouring, especially in the reddish varieties; but there is also beauty in the close texture, which takes on a fine polish. Large pieces often show the touch of life in their unexpected and very individual branching. We say 'the touch of life,' since the coral is a calcareous axis formed by microscopically minute contributions from the numerous polyps of a colony. There is no living matter in the coral itself, but the polyps that contribute to it are living enough. Each is a whitish creature about the size of a large pin's head, and somewhat resembling a miniature sea-anemone, but with eight feathery tentacles. They are connected to one another by reddish flesh, which is riddled by microscopic spicules of limestone; and these spicules fuse together, in some way not clearly understood, to form the hard and substantial core of calcium carbonate that is sold as 'coral.'

Some animals make a beautiful thing out of entirely extrinsic materials, as when a bird builds a nest of grass and moss, or when a sea-worm constructs, with the help of its tentacles, a tube of minute pebbles. But coral polyps make their axis out of material that has passed through the laboratory of their body, for the carbonate is not

the abundant salt of calcium in sea-water. The same may be said of the often exquisitely beautiful shells of molluscs, though these are moulded by the living tissue in a more intimate way than in the case of precious coral.

The word coral, modified from the Greek *korallion*, is said by Reinach to be of Celtic origin, while others refer it to a Hebrew root, *gôrâl*; but we must leave the Celts and the Hebrews to fight this out. What is more important, perhaps, is the fact that the use of coral as a decoration goes back to the fourth century B.C., and probably much further. It was one of the articles with which the early Mediterranean peoples traded.



FIG. 47. RED OR PRECIOUS CORAL (*Corallium rubrum*)

The polyps of the precious coral type are rather sensitive to changes of temperature, preferring 13°–16° Centigrade; thus the geographical distribution, though extensive, is discriminate. From the south coast of Ireland through the Bay of Biscay to Madeira, the Canaries, and the Cape Verde Islands, the precious corals occur; the Mediterranean is their chief home; they flourish well in Japanese waters and in the Malay Archipelago; there is an isolated occurrence off Mauritius. The actual fisheries are confined to the Mediterranean, Cape Verde, and Japan.

It should be noted that, besides the familiar 'coral-red' variety, there are others of different colours, white, pale pink, red-brown, and blackish-brown, the last not to be confused with the unrelated 'black coral.' The colour-varieties are usually restricted to particular localities—the blackish-brown to Algiers, the red-brown to Sicily, and the brilliant red to Sardinia; but all these are varieties of the one species, *Corallium rubrum*, the precious coral. There are other species of merit, some fetching £30 per pound.

Precious corals used to be collected by divers, but this was often fatal and has long since ceased. Moreover, the animals usually grow at depths which cannot be directly reached by man. A submarine boat has been tried by the Italians, but it does not seem to have proved a success. The usual method of capture is by some sort of combination of iron grapnel and loose net worked from a boat. In some cases the iron hooks are dispensed with, and half a dozen weighted yard-long tassels or tufts of horsehair and string are drawn over the coral banks. The entangled branches are thus torn off and brought to the surface. A device that sometimes yields very quaint results is to lower among the coral banks some hard object like a big barnacle. The object is left attached, and in a surprisingly short time its surface becomes beautifully encrusted with young corals, whose free-swimming

larval stages found attachment there. The result is a curious artificial-natural object.

The coral axis contains 83 to 87 per cent of calcium carbonate, deposited in the form of calcite. There is rather over 1 per cent of calcium sulphate and up to 6 per cent of magnesium carbonate, besides traces of other salts. There is only the slightest hint of iodine. The old idea that the varying colour of the precious coral is due to a varying percentage of oxide of iron has been disproved, but the colour is perhaps in part affected by the varying traces of organic matter in the core. The presence of this organic residue may be popularly demonstrated by heating a small piece of precious coral, for it gives off a distinct odour of burning horn.

There is a considerable parasitic industry concerned with faking precious coral, but it should be stated in fairness to our age that the idea is not modern. Many different substitutes are used, or have been used, such as ' vegetable ivory ' and ' ivory nut,' mixtures of rubber and gypsum, or of coral dust, white of egg, and some metal. Porcelain and marble are both used, but the commonest faking material to-day is galalith. Counterfeit coral beads are usually too light in weight and not cold enough to the touch. It requires some moral courage to take out a lens in the bazaar to look for the very delicate lines that mark the surface of true coral; but even a coward can take the beads in his hand!

Coral has been used in a great variety of ways—for beads, pins, brooches, ear-rings, cameos, paper-weights, chess-men, and so forth. It is sometimes very effectively combined with other beautiful materials, such as lapis lazuli, gold, pearls, and ivory. In some seats of the mighty it actually figures in mural decoration! In extremely rare cases coral has been used as money.

For many centuries coral was part of the pharmacopoeia, and was believed to cure all sorts of troubles, especially, of course, those connected with the blood. It would doubtless have an antacid effect, but probably no more. Coral powder is sometimes used to-day in Italy and other Mediterranean countries, both as a medicine and a dentifrice. Its use in tooth-cutting is familiar, but in many cases it was simply hung round the baby's neck as an amulet. We have read that there is in the National Gallery in London a picture of a marquise with a spray of precious coral in her hair.

Coral-fishing is nowadays a wholesome occupation, and it seems a great pity that one of the strange fluctuations of fashion should have led to its great reduction of recent years. In a scholarly treatise by Dr. Ferdinand Pax we read that in 1862 the export of coral from Europe amounted to a value of 12,000,000 marks; but there is probably only half as much to-day. The world production in 1906 was estimated

at 122,000 kilograms, but that of 1894 at six times more. There is no doubt that during the present century the demand for coral has greatly decreased, and we cannot but regard this as a sign of decadence.

The Alcyonarians include an astonishing variety of forms, some fleshy, some stony, some like fans and others like fungi, some like little trees and others like feathers, but the polyps are very much the same in all cases. Almost all of them have spicules of limestone—spindles, clubs, stars, capstans, needles, crosses, finger biscuits, dumb-bells, opera-glasses, a medley of different forms, reminding one of the variety of snow-crystals. In many cases there is much more lime-stone than living matter in the colony. Yet most of the Alcyonarians give out light! Many of them have partner-algae.

We can but mention the blue coral (*Heliopora*), an ancient stony colony of many reefs; the enormous red or white *Paragorgia* of Nor-wegian fjords which may grow to the height of a man; the sea-fans or *Gorgonias*, often a yard in expanse, so different in their gracefulness from the fleshy fungus-like relatives of dead men's fingers.

HOW CORALS FEED.—As we have noted, the corals that build up coral reefs are all related to the common sea-anemones of our shore pools, but most of them form colonies instead of remaining single individuals. Each is a more or less cylindrical animal, with a large number of stinging tentacles around the mouth, and with an external shell of limestone, which is gradually built up by the skin. The reef-builders are mostly carnivorous. They wait for little animals to come near, and then they capture them by means of lassoing and poisoning threads shot out from the stinging-cells on the tentacles and sides. Some experiments lately made by Dr. T. W. Vaughan show that the coral animals spread out their tentacles when they are hungry, and retract them when they are gorged. They accepted pieces of crab, but rejected vegetable food. Even quickly-moving minute crusta-ceans, so-called water-fleas, did not move quickly enough to escape the lightning-like dart of the coral's tentacles and lassos, we are told. Small particles of food caught on the rather slimy skin are wafted by living lashes to the mouth, but are swept away when the coral has had enough. But it should be noticed that some other kinds of corals, especially among the Alcyonarians, have a greenish colour, which is due to the presence of thousands of microscopic single-celled partner-algae in their cells. These partners or symbionts are able in the sun-light to build up sugar and other carbon-compounds, which the corals can use as food. So this is a case of *symbiosis* (p. 100).

SEA-PENS.—Standing by themselves in some ways are the sea-pens, which form among the Alcyonarians the order of **Pennatulids.** They are the only Alcyonarians that are not fixed, for the lower end of the pen is simply embedded in the mud or sand. Moreover, the

colony can move as a whole, which illustrates again that growing unity which is called integration (p. 70). Darwin noticed on his voyage on the *Beagle* that hundreds of a kind of sea-pen, projecting like stubble out of the muddy sand, would, when disturbed, suddenly draw themselves in with force so that they more or less disappeared. Most of the sea-pens have a rod running up the centre of what might be called the quill-stem, and it seems that this quill-stem is the greatly elongated and exaggerated first polyp of the colony, from which all the other polyps arise by often-repeated budding. But this is a difficult matter. It is easier to understand that in these colonies with a multitude of individuals there is **division of labour.** Besides the ordinary polyps which capture food and produce egg-cells and sperm-cells, there are much smaller individuals without tentacles (or sometimes with just one), that seem to keep up an aërating current of water in the colony. Technically the large individuals are called *autozooids* and the small ones *siphonozooids*, the word **zooid** meaning a living individual member of an animal colony. If we look at a common feather-like sea-pen, such as *Pennatula phosphorea*, thrown up on the beach and not too dry, we can see that the ordinary polyps occur along the margin of each of the leaves or pinnules, while there is a dense crowd of the dwarf individuals on the bare side of the quill-stem. **Dimorphism** (*di*, two; *morphe*, form) is the technical term used when two kinds of individuals are set apart in a colony, and the word **polymorphism** (*poly*, many; *morphe*, form) is used when there are more than two kinds of individuals, as in the Portuguese man-of-war. The same words will apply when the members of the colony are separate from one another, as in an ant-hill, not physically bound together, as in a sea-pen. A summary may be useful:

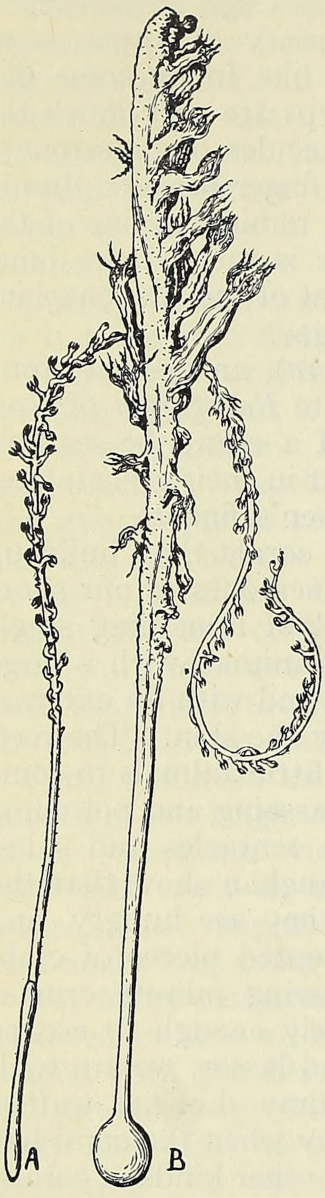


FIG. 48, A, B. SEA-PENS OR PENNATULIDS

Dimorphism (*two kinds of individuals*)

As in Sea-pens and some other Alcyonarians such as the mushroom-like *Sarcophytum*.

As in those Zoöphytes which have nutritive hydra-like individuals and quite different reproductive individuals.

Polymorphism (*more than two kinds of individuals*)

As in Portuguese Man-of-war and other Siphonophores.
As in an Ant-hill, with males, females, workers, and soldiers.

So far as observed, all the **sea-pens** are luminescent, but the use of this cold light, if any, is not known. It may possibly serve as a lure to minute animals that are captured as food, but it may be merely a sort of by-product of the chemical routine of the body. The word 'phosphorescence' should be discontinued for animal light which has nothing to do with phosphorus (see LUMINESCENCE).

A common British sea-pen is *Pennatula phosphorea*, about five inches in length, living at depths of ten to twenty fathoms, often cast up among the jetsam. It shows very clearly the lower naked quill or stalk, that is embedded in the sand, and the broader vane or *rachis* consisting of the quill-stem, as we may call it, and the pinnules or leaves. Some magnificent Pennatulas, with a very fine ruddy colour, are over two feet high, and one of their relatives called *Anthoptilum*, with polyps over an inch long, may attain to four feet. Some of the Deep-Sea kinds, like *Umbellula*, are very interesting in having the cluster of polyps forming the colony carried up on a long stalk high out of the treacherous smothering ooze. Common off American and some other coasts is the 'sea-pansy' (*Renilla*), where the vane or rachis part of the colony is flattened out into a heart-shaped disk with all the polyps on the upper surface. Preserved specimens have a violet colour. Most of the sea-pens are bilateral and wonderfully graceful; a few, like *Cavernularia*, are more like swollen fingers and radial in their symmetry.

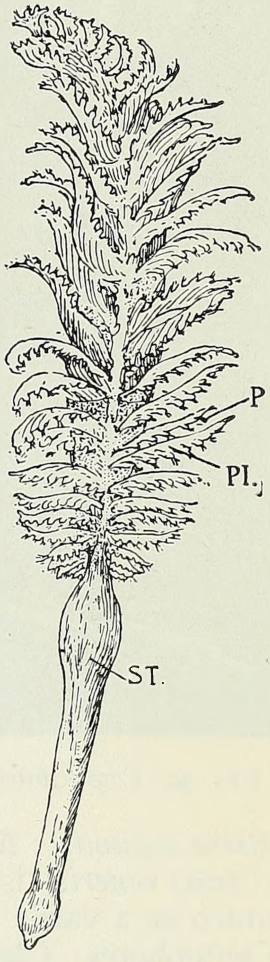


FIG. 49. SEA-PEN (*Pennatula*)
P, polyp; Pl, pinnule; ST, stalk.

COMB-BEARERS OR CTENOPHORES.—These beautiful animals are characteristic of the Open Sea, very delicate in build, often as clear as crystal, usually luminescent. They feed on small animals, sometimes as high up in the scale as larval fishes; and in almost all cases the usual stinging-cells of Coelentera are replaced by adhesive or glue-cells which grip the booty. A very

interesting, though technical, feature is the establishment of a definite middle layer of cells—**mesoderm** instead of a mesogloea. The name Ctenophore (*cteno*, comb; *phore*, bearer) refers to the fact that in every case save one there are plates or combs consisting of a row of cilia, fused at the base and free at the edge. These plates or combs usually occur on eight ridges running from pole to pole of the body, which is in most cases globular or thimble-shaped (hence the name 'sea-gooseberries'). They are alternately raised and flattened and they work in succession towards the mouth, which is foremost when the animal is swimming. At the centre of the other pole there is a balancing organ. The swimming is very gentle and the body is exceedingly delicate. It is not surprising, therefore, that the Ctenophores sink below the surface in stormy weather. The sexes are combined and there are sometimes larval forms very different from the adults.

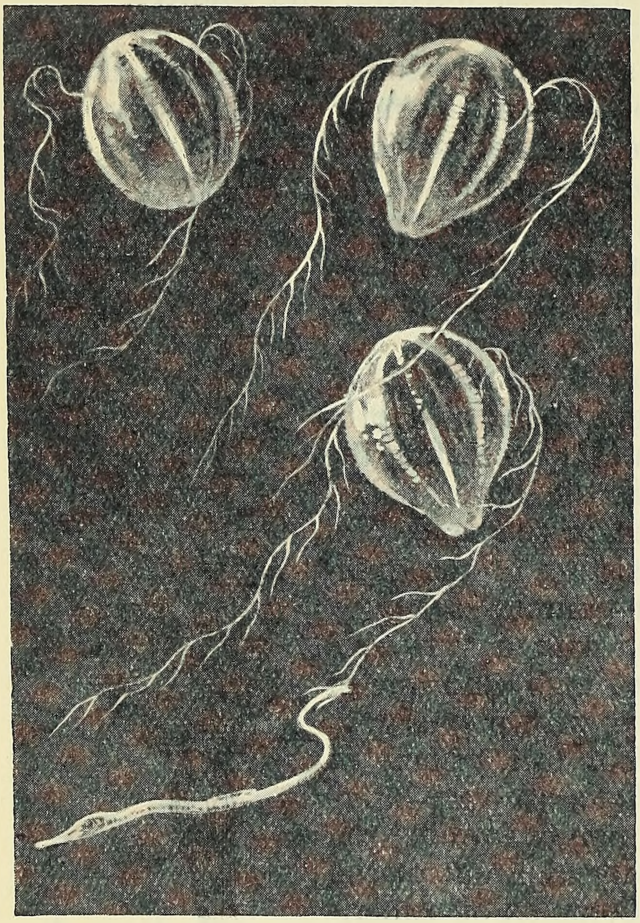


FIG. 50. CTENOPHORE OR SEA-GOOSEBERRY

Some of the common comb-bearers of British seas are popularly called 'sea-gooseberries,' such as *Pleurobrachia pileus* and *Beroë cucumis*. A very strange Mediterranean form, the Venus's girdle (*Cestus veneris*), is drawn out like a transparent strap to a length of as much as a yard. Of great interest to the zoologist are two creeping Ctenophores, *Ctenoplana* and *Coeloplana*, and a sedentary type called *Tjalfiella*, for they seem to point the way to the simplest 'worms,' the *Planarians* or *Turbellarians*. So it is fitting that we should end our review of a large phylum, with a finger-post pointing on to something higher.

Survey of Phylum Coelentera or Stinging Animals

I. Class: **Hydrozoa.** Hydra and the hydroid or Zoöphyte colonies; the Swimming-bells or Medusoids, most of which are the liberated reproductive buds of Zoöphyte colonies.

II. Class: **Scyphozoa.** The true Jellyfishes or Medusae.

III. Class: **Anthozoa.** The Sea-anemones and the Madrepore Corals; the Black Corals or Antipatharians. All these are grouped as Zoantharians, most of them with parts in multiples of six. On another line are the Alcyonarians, with eight as the ruling number, such as red corals, sea-fans, and sea-pens.

IV. Class: **Ctenophores** or Comb-bearers. These are far apart from the others and practically without stinging-cells.

Here it may be convenient to notice again that there are many different kinds of **corals**:

(1) Zoöphyte corals called Millepores.
(2) Zoöphyte corals called Stylasters.
(3) Madrepore corals, both solitary and colonial.
(4) Black corals or Antipatharian corals, with no limestone.
(5) Alcyonarian corals, such as the red corals and blue corals.
(6) Extinct corals, not belonging to any of these groups.

The word coral may also be extended to include hard colonies of much higher animals, the *Bryozoa* and some worms.

CHAPTER VI

THE FLAT WORMS OR PLATYHELMINTHES

Worms a heterogeneous assemblage—Acquisitions made by worms—Survey of the first phylum: the Flat Worms—Turbellarians or Planarians—Asexual multiplication—Regeneration—Flukes or Trematodes—Life-history of the Liver-fluke—The story of Bilharzia—One of the most extraordinary of parasites—Tapeworms and Bladderworms: Cestodes—The story of 'Sturdie'—Parasitism in general—Pearls.

WORMS A HETEROGENEOUS ASSEMBLAGE.—When we say 'even the worm will turn,' we think at once of the common earthworm. But there are hundreds of different kinds of 'worms,' which form a sort of mob, not yet in good order. The fact is that the word 'worm' is little more than a convenient name for any animal with an elongated shape. Thus earthworms and lob-worms, land-leeches and water-leeches, ribbon-worms, threadworms, tapeworms, fluke-worms, and many more besides, are all 'worms'; but some of the classes are very distantly related to others. In short, we must think of 'worms' as an assemblage of diverse classes.

ACQUISITIONS MADE BY WORMS.—It was, however, among worms that certain great advances were made. (*a*) The cup-like or disk-like *radial* symmetry of sponges and most stinging animals was replaced by right-and-left or *bilateral* symmetry, which proved itself very much more effective for energetic life. A bilaterally symmetrical animal has a right side and a left side, a head end and a tail end. This shape is suited for active movement, one end of the body always taking the lead. It is suited for energetic life, pursuing prey, avoiding enemies, and chasing mates, whereas radial symmetry is well suited for drifting or moving aimlessly, or for waiting, fixed to a rock, for food to drop into the tentacled mouth.

(*b*) With certain worms there began the first **head-brains,** arising from an in-sinking of outer-layer (ectoderm) cells at the front end, which must be the most experienced part of the body. This was the beginning of a centralized nervous system, very different from the nerve-network of a sea-anemone. It should be noted here that the brain of a higher animal always arises in the embryo as an in-sinking of surface-cells; and that was its historical origin in the evolution of the race.

(*c*) We have explained that in sponges and stinging animals there

are in the body of the embryo and adult two well-defined layers of cells with different characters—the *ectoderm* and the *endoderm*, between which there may be developed an ill-defined stratum, the middle-jelly or *mesogloea*, very well seen in jellyfishes. In the sea-gooseberries, or Ctenophores, a middle layer of cells makes its appearance. This is established in worms, and is thenceforth always present. It is called the **mesoderm,** and it forms such tissues as muscles. Animals that have only two fundamental layers of cells (sponges and stinging animals) are called **diploblastic** (p. 72) (*diplo*, double; *blastos*, a germ), whereas all animals from worms onwards are called **triploblastic.** Thus, apart from Ctenophores, worms begin the long series of triploblastic creatures culminating in Man.

(*d*) Besides bilateral symmetry, head-brains, and a mesoderm, there is another acquisition that 'worms' made, but it is not clearly seen below the level of earthworms and lob-worms. This new acquisition is the **body-cavity** or **coelom,** a space between the food-canal and the body-wall. In a sea-anemone or jellyfish there is only one cavity in the body, and that is the food-canal; but in an earthworm and most of the higher animals there is a body-cavity through which the food-canal passes. It is lined to the outside and the inside with mesoderm; it usually contains a fluid, often with floating cells; it is shut off from the blood system; it often communicates with the outer world by means of kidney-tubes or other ducts; it usually bears the reproductive organs on its internal wall. It is not always easy to be clear about this body-cavity or coelom, and we shall have to return to it. But it was one of the important acquisitions for which we have to thank certain ancient and primitive worms.

SURVEY OF THE FIRST PHYLUM: THE FLAT WORMS.—The lowest worms are the flat worms, including three chief classes: Turbellarians, Flukes, and Tapeworms. As these are related to one another, they form a series of classes (a *phylum*, as we have explained already), technically called **Platyhelminthes** (*platy*, flat; *helminthes*, worms). What characters have they in common?

The body is flattened out from above downwards, like a leaf in *Turbellarians*, like a trowel or a flounder in the *Flukes*, and like a long tape in the *Tapeworms*. There is the beginning of a head-brain in the Turbellarians, but there is naturally not much of this to be seen in Flukes and Tapeworms which are parasitic and degenerate. The middle layer or mesoderm forms a compact packing tissue in which the organs are embedded, so that no body-cavity is definitely developed. Almost all flat worms have the sexes combined. The eggs are almost always in shells. There is a very characteristic excretory system, which consists of a pair of lateral canals receiving many tributaries, like a drainage-system—as of course it is. When the

very end of a fine tributary is examined under high magnification, a peculiar kind of cell is seen — a **flame-cell.** All flat worms have flame-cells, just as all sponges have collared lashed cells, and almost all Coelentera have stinging-cells. A flame-cell is a large hollow cell with (*a*) amoeboid processes at its free end, and (*b*) quivering lashes or flagella at the other end, where it joins on to the fine tributary of the excretory tube. The lashing action of the flagella, driving waste products into the excretory vessel, suggests a flickering flame, hence the name flame-cell. We have given this little detail because it is interesting to find a particular kind of cell in all the members of a number of classes. It proves their blood-relationship—though there is not as yet any blood! There are no flame-cells in round worms, which shows, again, that these animals are on a different line of evolution. Cells somewhat similar to flame-cells are found in some of the much higher bristle-footed marine worms (*Polychaets*).

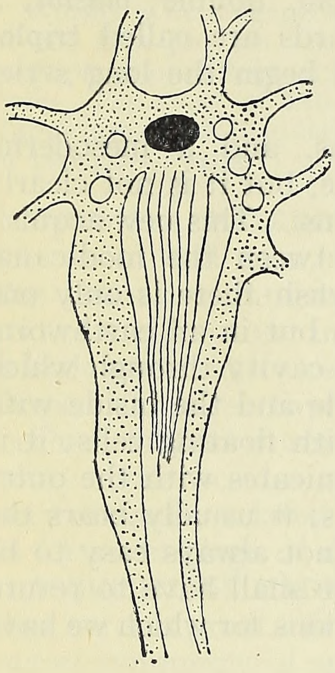


FIG. 51. A FLAME-CELL

The flat worms show an interesting inclined plane of habit. The Turbellarians or Planarians are free-living, except a few marine kinds that have taken to parasitism; the Trematodes are all parasitic, but many of them are external hangers-on (ectoparasites), on the gills of fishes, for instance, while the rest, like the liver-fluke, are internal unpaying boarders (endoparasites); and, thirdly, the tapeworms are altogether internal parasites.

TURBELLARIANS OR PLANARIANS.—These are the simplest worms, unsegmented and usually leaf-like, covered with lashes or cilia. They live in fresh, brackish, or salt water, or in moist earth. Almost all are carnivorous, a few are parasitic. The mouth, which may be in the centre of the under-surface, leads into a blind food-canal, often branched. They move in a graceful way by means of their cilia, helped by muscle-cells. They often look like leaves mysteriously moving, or like 'living films.' Most of them are small, but some attain to a length of six inches or more. As examples may be mentioned: *Planaria* in fresh water, *Leptoplana* in shore pools, *Bipalium* in damp earth (sometimes imported into Britain).

ASEXUAL MULTIPLICATION.—When a simple turbellarian worm like Planaria exceeds a certain length, a line of weakness appears about two-thirds of the way from the head. The vital processes sink to a minimum at this line, and then increase again, finally waning to

the tail end. At this line of weakness the control that the head exerts on the growth of the region behind it seems to find its limit, and a new head begins to be formed. It is as if a mutiny of cells took place, or we might compare it to the pushing-out of buds when the growing-point of a stem has been raised to a certain distance above their origin. Here, both in plant and animal, we have an instance of the *control* that one part of a body may exercise on the growth of another part. This is called **correlation.** But to return to the growing simple worm, Planaria: it forms a second head; and if a check should come to nutrition, the posterior fraction of the worm may separate off by itself. This is a clear case of *asexual multiplication*. It sometimes happens that a chain of four or more Planarian individuals is formed before separation takes place.

When we see an animal multiplying readily by dividing into two, as in Planarians, or by giving off a bud, as in *Hydra*, we cannot but ask why this asexual multiplication has been quite superseded in most higher forms of life by sexual multiplication, or why an animal like Planaria that can multiply asexually should also have eggs and sperms. It is hardly enough to say that the complexity of the higher animals makes asexual multiplication impracticable, for we find that some very intricate animals like sea-squirts multiply asexually. There must be great advantages attendant on the establishment of sexual multiplication—by separating off special germ-cells, the eggs and sperms. What are these advantages? (*a*) Many more new lines can be started at once by the liberation of germ-cells than by giving off buds or large pieces. (*b*) When a bud or fragment is given off to start a new individual, it must carry with it any deteriorations that have affected the parent body, as actually happens when a deteriorated potato tuber is cut up and used for planting out. But this carrying on of bodily deteriorations, weakenings, poisonings, and so on is very much less likely to occur when the new lives are started from egg-cells and sperm-cells which did not share in any active way in the life of the parent body. (*c*) When the egg-cells of one individual animal are fertilized by the sperm-cells of another individual of the same kind, as usually happens, then this cross-fertilization means a pooling or combination of the inheritances of the two parents. Thus defects may be counterbalanced and new departures may be provoked. These are three reasons why the sexual mode of multiplying, by egg-cells and sperm-cells, has proved a success in evolution.

REGENERATION.—This word is used technically in biology for the regrowth or replacement of lost parts. It is a continuation of the everyday replacement of lost or worn-out cells, or of the process of healing wounds. It cannot be separated from the replacement of a moulted feather or a shed hair, but the word is most often used when

there is a regrowth of a part that has been cut or broken off—in combat, for instance—or is for some other reason wanting. Thus a lizard will regenerate a tail to replace the one that has been broken off by a bird's beak. So with a newt's leg or even its eye; so with a snail's horn or a crab's claw; so with a starfish's arm or with the head end or the tail end of a Planarian worm. Indeed, if a Planarian be cut across into four pieces, each of these may regenerate a complete worm.

There are two ways of looking at this **power of regrowth,** which is so familiar in pruned trees and the like. It means that the cells of the body or of particular parts of the body retain the power of giving rise to structures quite different from themselves. How should the stump of a snail's horn be able to replace the little black eye at the tip? Certain cells must retain all the possibilities of embryo-cells, just as those in a cut-off piece of begonia leaf prove themselves to have retained the power of developing an entire plant—root and stem, leaf and flower. Many leaves and many other pieces of plants have this power, and so is it, but much more restrictedly, with animals.

But there is another way of looking at this power of replacing lost parts. It seems to occur where it is most likely to be wanted. That is to say, in the course of time the regenerating power has persisted where it is useful, and has more or less disappeared where it is superfluous. Most lizards can regrow a tail to replace a lost one; but the chamaeleon has not this power. May not this be because the chamaeleon coils its tail round a branch and is not likely to have it snapped at by birds? Or, again, it is rather striking that while the replacement of lost or injured external parts is common, this is very rarely the case with internal organs, except, indeed, along with a whole region of the body, as in the case of worms. May not this be because an injury serious enough to remove an *internal* organ would almost necessarily prove fatal, and a power of regrowth would not save the situation?

It should also be noticed that the power of replacing lost parts becomes less and less among the higher animals. We ourselves can regrow a piece of lost skin, but little more, and so it is with mammals generally. For we must not include regular normal replacements, such as new hairs, or the second set of teeth after the first, or the stag's annual growth of antlers. The highest illustration of the regeneration of lost parts is probably the replacement of a considerable portion of a stork's bill after a savage fight. When the lizard replaces its lost tail, it does so in a somewhat makeshift way. The new tail is not nearly so well-made as the original one.

Why is it that the power of regrowing lost parts wanes away among higher animals? Partly because higher animals are more complex;

partly because a serious loss or injury is more likely to be fatal in a higher animal; but also because a creature like a bird or a mammal has developed keen wits, which often suggest a way of avoiding such a loss as a crab or a starfish has to endure.

The Italian naturalist Lessona suggested that the power of regrowing lost parts tends to occur in those animals and in those parts of animals which are, in the natural conditions of their life, peculiarly liable to non-fatal injury. This is known as **Lessona's Law.** If regeneration is possible at all, one naturally looks for it in lanky, long-legged, long-tailed, brittle animals. One would not expect much of it in a sea-urchin; though it is very marked in starfishes and sand-stars.

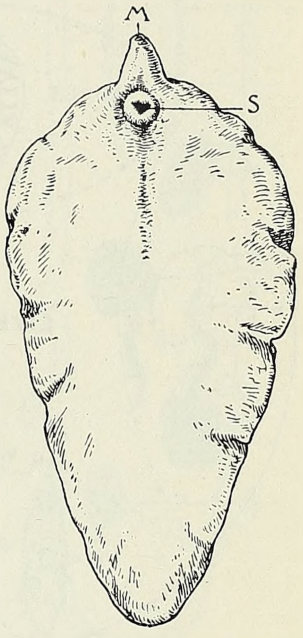


Fig. 52. The Liver-fluke (*Distomum hepaticum*)
M, mouth; S, ventral sucker.

FLUKES OR TREMATODES.—These are flat parasites, usually leaf-like, hanging on to other animals, or living deep in the interior, but always getting their food from a living host without much exertion. In most ways they are like Turbellarians, from which they probably sprang. But they are not covered with cilia and they usually have some suctorial apparatus for fixing themselves to their host. The food-canal is forked or much branched, and it always ends blindly. In almost all cases the sexes are combined, and self-fertilization often occurs. As adults they live on or in backboned animals, but many of them have two hosts and then the host of the young stages is often a backboneless animal. Thus the liver-fluke of the sheep passes its larval stages in a freshwater snail.

LIFE-HISTORY OF THE LIVER-FLUKE.—Sheep are sometimes infected with a serious disease called liver-rot, which is due to the presence of liver-flukes (*Distomum hepaticum*) in the tributaries of the bile-duct of the liver. The parasites feed on the blood of the sheep's liver, and they occasionally occur in cattle, horses, and many other mammals. It is not usual for a particular kind of parasite to occur in many different hosts; the liver-fluke is exceptional. A liver-fluke is leaf-like and shaped like a trowel; it is about an inch long, by half an inch across its broadest part; the colour is reddish brown to greyish yellow. The name Distomum (*di*, double; *stoma*, mouth) implies that there are two mouths; but all that can be said is that there are two suckers. The anterior one, at the very tip of the leaf-like body, is perforated by the mouth, and a muscular region behind the mouth (called the **pharynx**) sucks in the blood of the liver, for it is on the

blood that the fluke feeds. The second sucker, a little way behind the mouth on the mid-ventral line, is solely for adhesion—that is to say, for hanging on to the wall of the bile-duct tributary. The food-canal is much branched and can hold a relatively large quantity of blood, but it ends blindly. There is a very simple nervous system and there are no sense-organs in the adult. There is no blood system, or breathing system; but there is a very elaborate arrangement, like a river with many tributaries, for draining away the nitrogenous waste-products. The liver-fluke combines both sexes (**hermaphrodite**) and has very complex reproductive organs; it is unusual in fertilizing its own eggs (**autogamous**).

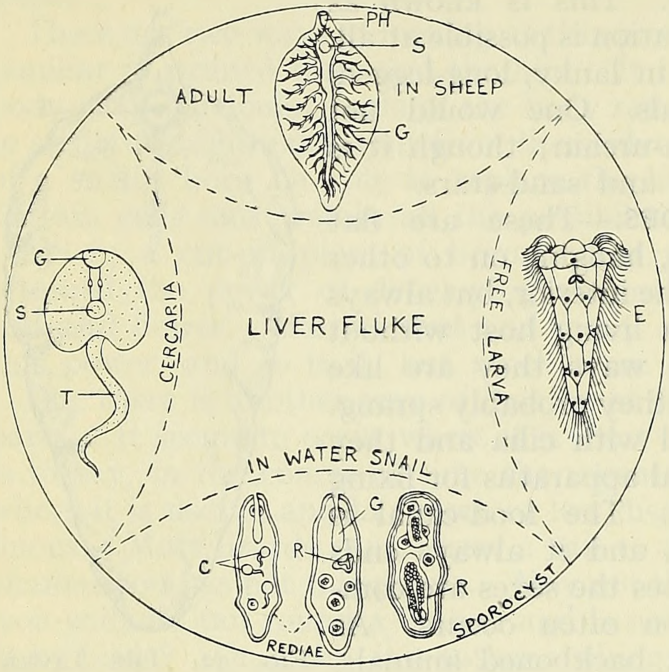


FIG. 53. LIFE-HISTORY OF THE LIVER-FLUKE

Upper quadrant, adult in sheep. PH, pharynx; S, sucker; G, gut.

Right quadrant, free-swimming larva, with eye-spots (E).

Lower quadrant, sporocyst and rediae in water-snail. R, redia within sporocyst or within redia; G, gut in redia; C, cercariae in redia.

Left quadrant, free cercaria. G, gut; S, sucker; T, tail.

The liver-fluke is a prolific animal; it may produce fifty thousand eggs. This means that the chances of death in the young stages are so great that the race of liver-flukes could be continued only by those types that varied in the direction of being prolific. It may also mean that the somewhat luxurious conditions of life in the warm and sheltered liver, with abundance of food to be had without much exertion, favour prolific multiplication.

The egg is encased in a shell and surrounded by yolk-cells. Many are liberated at a time and pass down the bile-duct, developing as they go, into the food-canal, and thence to the ground with the sheep's droppings. Outside the sheep the development of the egg continues amid damp grass or in a pool of water, and in a few weeks there emerges a microscopic ciliated larva, known as a *miracidium*. It is provided with two eye-spots and continues swimming actively for a few hours. It may touch various things, but it is arrested only by the little freshwater snail (*Limnaea truncatula*). If this is not found

in eight hours the larva dies. There are other species of Limnaea, but in Great Britain the only one that will serve for the continuance of the liver-fluke's life-history is the small one above mentioned. Its length is about the breadth of our little finger-nail.

The larva or miracidium works its way into the water-snail, entering by the breathing aperture. It settles down in the breathing-chamber, loses its cilia and eye-spots, increases in size and becomes a hollow sac, called a *sporocyst*. But this soon falls victim to precocious asexual reproduction, giving rise inside itself to from five to eight second larvae (with a short and simple food-canal), called *rediae*. In the summer-time these second larvae give rise to more (eight to twelve) rediae, and these finally produce (twelve to twenty) little tailed third larvae called *cercariae*. These leave the dying snail and leave the water; they climb up blades of grass, lose their tail, and encyst themselves as minute white spots visible to the naked eye. If the sheep eats the grass, then the cercaria, becoming active in the food-canal, passes up the bile-duct into the liver, and in six weeks or so becomes a fully-formed young fluke.

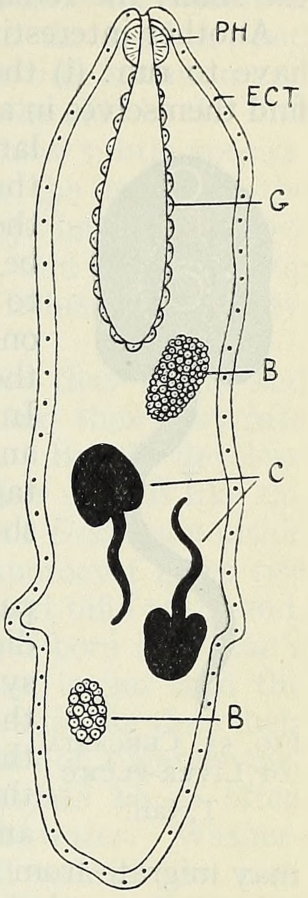


FIG. 54. REDIA OF LIVER-FLUKE

PH, pharynx; ECT, ectoderm; G, gut; B, ball of cells or morula capable of growing into cercariae (C).

This life-history illustrates **alternation of generations** (p. 88), somewhat similar to what we have described in some zoöphytes and in some jellyfishes. But in this case there are two or three asexual stages—the sporocyst and two sets of rediae. In winter it seems that a sporocyst may give rise directly to the cercariae, but even then there would be alternation of generations. The summer story may be indicated thus:

SPOROCYST→SPORE-CELL→REDIA→SPORE-CELL→REDIA→SPORE-CELL
↑ ↓
MIRACIDIUM CERCARIA
↑ ↓
EMBRYO ADULT FLUKE
↑ ↓
FERTILIZED EGG-CELL FERTILIZED EGG-CELL

An interesting feature is the increasing number of young forms with successive multiplications. Thus a sporocyst may give rise to from five to eight first rediae, a first redia may give rise to from eight

to twelve second rediae, a second redia may give rise to from twelve to twenty cercariae. The sporocyst lives in the breathing-chamber of the snail; the rediae in the snail's liver.

Another interesting feature is the number of risks the young stages have to run: (i) the eggs might land on dry ground; (ii) they might find themselves in a pool without a water-snail; (iii) the free-swimming larvae might fail to find their water-snail host within the first eight hours, which is about the length of their life; (iv) the snail into which they enter might be eaten by a water-wagtail, and this would be fatal to the parasites as well; (v) the cercariae encysted on the grass might be dried up by the sun; and (vi) the blade of grass might never be eaten by a sheep. In any of these ways the life-history might come to an end, and we can well understand that it is advantageous for the race of liver-flukes that the individuals should be prolific.

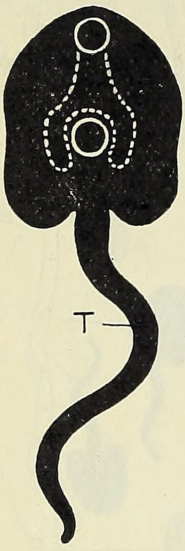


FIG. 55. CERCARIA OF LIVER-FLUKE
T, tail.

Liver-rot in sheep is commonest in undrained pasturage, where water-snails are abundant; and the disease is favoured by very rainy seasons. The symptoms in the sheep are many; there is paleness of the eyes and gums; the animal becomes weak and thin; a watery bag develops below the lower jaw; the breathing is difficult; even the wool becomes dry and brittle. A full-grown fluke that has reproduced may migrate from the sheep, or it may die in the liver; but too often it is the sheep that dies. The disease is becoming less common where drainage is practicable. It is useful to treat 'fluky ground' with salt or with salt and lime. Suspected sheep should be isolated and their droppings burnt; those left should get good food and some salt. It is plain that wagtails and lapwings should be encouraged in the interests of sheep-farming.

THE STORY OF BILHARZIA.—One of the serious parasites of man is a fluke called *Bilharzia*. Its still more technical name is *Schistosomum*, and there are several different kinds. It is one of the Trematodes, but it looks more like a round worm or Nematode, for the body is like a narrow grass-leaf folded in lengthwise on itself. The sexes are separate and the male, about half an inch in length, carries the female, about twice as long, in a groove of his body. Bilharzia is in many ways very different from the liver-fluke, but it resembles it in having its young stages in freshwater snails, such as *Planorbis*, *Bulinus*, and *Isidora*. Till a few years ago, every third child born in Cairo became infected with this worm; and in some warm countries there are places, it is said, where every fourth man is infected. One of the

kinds, called *Schistosomum mansoni*, lives in the blood-vessels of the intestine, and the enshelled eggs pass out with the faeces or undigested residue of the food. Another kind, called *Schistosomum haematobium*, lives in the blood-vessels of the kidney region and the bladder, and its eggs pass out with the urine. Both kinds cause inflammation and much pain, for the egg-shell has a sharp spine, at the side in the first species, at one end in the other species (showing how subtle species-differences often are), and these spines cut into the walls of the blood-vessels and the like. British soldiers in Egypt have sometimes suffered badly from this contemptible little worm, and it was during the Great War that Major Leiper discovered its life-history and how the risks of infection might be greatly lessened.

If the enshelled developing eggs pass into water they hatch and give rise to free-swimming ciliated larvae which find their way into freshwater snails, just as in the case of the liver-fluke. But the development of the larval *Bilharzia* in the *Planorbis* or other snail is like the winter development, not the summer development, of *Distomum* inside *Limnaea*. Thus there is no redia stage and the sporocyst gives rise directly to minute cercariae. These are thread-like and bifid at the end. They swim actively in the water for some time and bore into man's skin if they get an opportunity. If a dead mouse is put into the water, the cercariae soon find their way in, and we suppose that their normal host is some aquatic mammal with the habits of a water-vole. It is not difficult to understand why children should be so often infected; it must be largely because they paddle in the water. Washer-women are often victims for obvious reasons, and so with the men who spray the gardens with unfiltered water. The possibility of infection will be increased when there are cracks or scratches in the skin. Major Leiper found that if the water is kept perfectly still in cisterns or the like for thirty-six hours, the cercariae all die; and this is a simple way of lessening the risks of infection. It may be noted that well-filtered drinking-water is not a source of infection, for the cercariae, minute and delicate as they are, cannot pass through a really good filter. This life-history of Bilharzia is of practical importance, and it is also a good example of a knot in the ' web of life ' —for man and the water-snail and the minute worm are all tied together in the tangle.

The water-snails that serve as the hosts of the young larvae of Bilharzia feed on water-plants, such as water-lilies; and an accumulation of vegetation will increase the number of snails, whereas clearing out the ponds will act as a check. If water-birds are encouraged, they will keep down the water-snails. In places like Durban, where man is the only host of the adult Bilharzia, the most important thing is to keep the water-pools from being contaminated with the

microscopic eggs that are passed out from the infected man, woman, or child. But in Japan, where cattle are also carriers of the adult Bilharzia, it may often be very difficult to keep the water from being fouled by beasts standing in the pool. Man is sometimes infected by the mouth, though usually by the skin, and the difficulty of dealing with these knots in the web of life may be illustrated by the report that people may be infected from lettuce and the like which have been steeped in unfiltered water containing the microscopic larvae or cercariae. The plants should be well washed in water to which a little sodium sulphate has been added.

ONE OF THE MOST EXTRAORDINARY OF PARASITES.—A remarkable fluke called *Leucochloridium macrostomum*, well known on the continent of Europe, lives in the intestine of singing birds, whence the microscopic eggs are voided on the meadow. They are eaten by a snail (*Succinea putris*) and, hatching in the stomach, give rise to active larvae. An active larva (let us suppose that only one egg was swallowed) bores out of the stomach, and becomes in the body of the snail a relatively large-branched body (a sporocyst). The central part of this transformed larva absorbs nutriment from the snail; the branched parts reach the snail's horns and become reproductive. They distend the horns, and bring about the deposition of bands of red and green pigment. Each branch contains eventually over a hundred young flukes (cercariae) of the next generation!

The terminal reproductive branches are very muscular, and they pulsate rapidly inside the horns, contracting and expanding sometimes twice a second. If a blackcap or some similar perching songster is attracted by the snail on a leaf and bites off the agitated horn, the contained bags of larvae close up automatically at their bases, so that the progeny is not lost. It is said that if the bird swallows the titbit the result is nil—the parasites are digested. But if the bird gives the titbit to its nestling, with weaker digestion, then infection occurs and the cycle begins again. The queer things about parasites are many, but this is one of the queerest.

TAPEWORMS AND BLADDERWORMS: CESTODES.—A typical tapeworm (*Taenia*) is like a piece of wet white tape. There are some very small and slender, and a few thickish and compact, but most are true to their name. At one end is the attaching head; then comes a slender growing neck; this leads to a chain of joints. This chain may be several feet in length; the end links are always dropping off and new ones take shape at the lower end of the neck. The head is technically called the *scolex*, and each joint a *proglottis*.

With one exception (*Archigetes*), tapeworms live in backboned animals, and when one thinks of their length and of the need for getting sustenance, one recognizes that the food-canal, and the

intestine in particular, must be their usual home. But the young asexual stage of the tapeworm, known as the bladderworm (or *proscolex*), lives in some animal that the final host eats, and this may be a backboned or a backboneless animal. Thus the tapeworm of the cat has its bladderworm in the mouse, but one of the tapeworms of

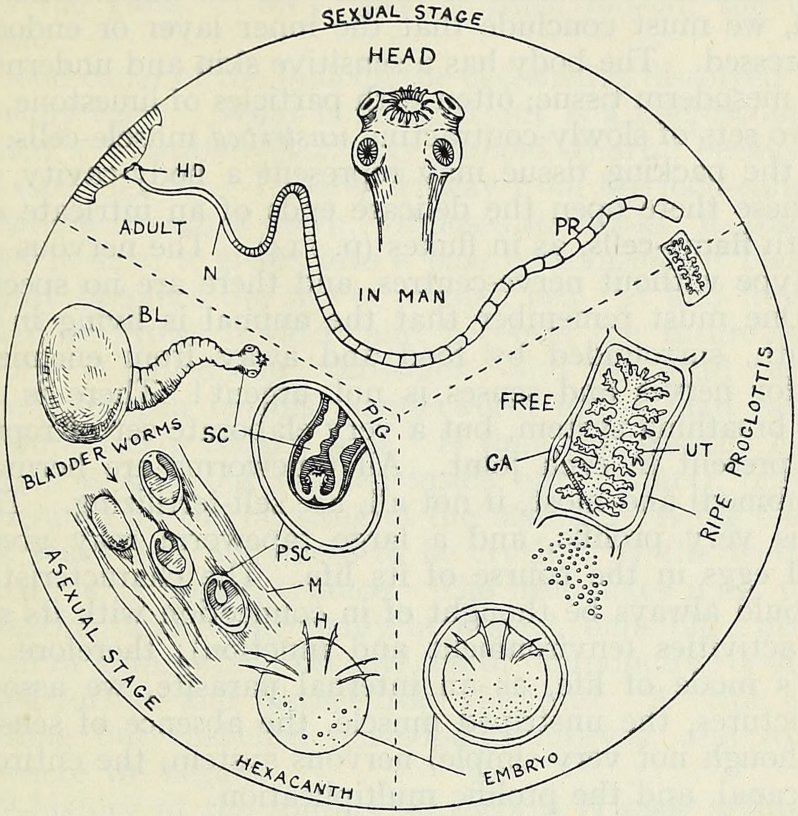


FIG. 56. THE TAPEWORM (*Taenia solium*) AND ITS LIFE-HISTORY

(i) In man: HD, head; N, neck; PR, proglottides.

(ii) Free-living: Free proglottis and egg-cases. UT, uterus; GA, genital aperture; embryo within the egg-case.

(iii) In the pig: H, hexacanth embryo; PSC, proscolex; M, muscle of pig; SC, scolex; BL, bladder.

the dog has its minute bladderworm stage in the dog-flea. In the majority of cases the bladderworm lives in the muscles of its host.

A full-grown tapeworm has its head fastened to the wall of its host's intestine, and the tape-like body floats backwards from this mooring. As the wall of the intestine, with its *smooth* muscles, is always contracting (**peristalsis**) and driving the half-digested food onwards, the tapeworm would soon be expelled were it not firmly attached by its head. This attachment is effected by muscular suckers, sometimes helped by hooks and a proboscis. There is no mouth or food-canal, and thus we understand better the significance

of the great length and flat surface of the tapeworm, for it is through this large surface that the fluid food is absorbed. This food, in which the tapeworm may be said to float, is the digested food of its host. It is this getting of food without exertion that seems to us the most characteristic feature of **parasitism**—not the mere living in the inside or on the surface of another creature. As the tapeworms have no food-canal, we must conclude that the inner layer or endoderm has been suppressed. The body has a sensitive skin and underneath that a packing mesoderm tissue, often with particles of limestone, and with at least two sets of slowly-contracting *unstriped* muscle-cells. Minute spaces in the packing tissue may represent a body-cavity, and into some of these there open the delicate ends of an intricate excretory system with **flame-cells**, as in flukes (p. 114). The nervous system is of a low type without nerve-centres, and there are no special sense-organs. One must remember that the animal is living in darkness and warmth, surrounded by food and away from enemies. Thus the need for nerves and senses is not urgent! There is no blood system or breathing system, but a very elaborate set of reproductive organs is present in each joint. All tapeworms are hermaphrodite (sexes combined) and most, if not all, are self-fertilizing. The multiplication is very prolific, and a large tapeworm may give rise to millions of eggs in the course of its life. The characteristics of an animal should always be thought of in connection with its surroundings and activities (environment and function); therefore with the tapeworm's mode of life, as an internal parasite, we associate the fixing structures, the unstriped muscle, the absence of sense-organs, the low (though not very simple) nervous system, the entire absence of a food-canal, and the prolific multiplication.

LIFE-HISTORY OF A COMMON TAPEWORM OF MAN.—The commonest tapeworm found in man in Britain is called *Taenia saginata*, with its bladderworm stage in the ox; the commonest on the Continent is called *Taenia solium*, with its bladderworm stage in the pig. In either case man is infected by eating flesh imperfectly cooked, such as a very much under-done steak or a sausage of very red pig's flesh. It is by unconsciously swallowing the bladderworm or its minute head that man becomes infected with tapeworm.

The tapeworm has an attaching head about the size of a pin's; it bears four attaching suckers, which have nothing to do with feeding. In *Taenia solium* there is also a circlet of minute crochet-needle-like hooks. The chain of joints may be several feet in length, and the joints develop complex reproductive organs as they get shunted further and further from the head.

The last joint is liberated (sometimes along with others) and passes down the intestine to the exterior. It has some power of muscular

contraction and weak movement, and it is distended with microscopic developing embryos, enclosed in firm egg-shells, and these are set free if the joint is burst. This might happen on the grass, and the firm shells enable the embryos to resist death for some time. It is possible that the enshelled embryos may be swallowed by a bullock as it eats the grass. Unless this happens, indeed, the life-history is at an end.

In the food-canal of the bullock the egg-shell is dissolved (and there may be many eggs). What is hatched out is a microscopic globular larva, called a *hexacanth* (*hex*, six; *acantha*, thorn), because it bears six hooks (see Fig. 56). It bores its way from the food-canal into the muscles, where it settles down. It loses its hooks; it absorbs fluid; it increases in size; it grows into a passive translucent bladderworm, which finally becomes the size of a small pea. A bud from one side of the bladder grows inwards and becomes the future head. The bladderworm is called the ' proscolex ' and the head the ' scolex.' Nothing will happen to this bladderworm unless man eats it along with the imperfectly cooked beef. If that happens the head of the bladderworm is shot out (turned inside out, in fact), or it may be simply liberated by the bursting of the bladder. Being only the size of a pin's head, it is not likely to be crushed by the teeth, and the bladder part is of no importance. The head fixes itself to the wall of the intestine, and, being richly nourished, buds off a neck portion and a chain of joints which become full of reproductive organs as they are shunted further and further from the head. A ' ripe joint ' contains nothing but enshelled developing embryos, and so we come back to where we began.

The life-history of the solitary tapeworm (*Taenia solium*), which, if present in man's intestine, is usually in the singular, is just the same as that which we have outlined, except that for bullock or ox we must read pig. Most of the Cestodes have the same kind of life-history: fertilized egg, developing embryo, free hexacanth larva, bladderworm, tapeworm; and the rule is that the host of the tapeworm is an animal that normally eats the host of the bladderworm. In some cases the proscolex stage is a tailed larva, not like a bladder; and in some cases the hexacanth stage is represented by a ciliated free-swimming larva which takes our thoughts back to the story of the liver-fluke. In the great northern plain of Europe, stretching eastwards along the shores of the Baltic, the inhabitants are often troubled with the broad tapeworm (*Bothriocephalus latus*), which may attain a length of eleven yards. It has two elongated suckers on its head, and the joints are not so distinctly marked off as in Taenia. Now this broad tapeworm has its young stage (without a distinct bladder) in such freshwater fishes as trout, pike, and burbot; and man becomes

infected by eating these fishes imperfectly cooked. It often happens that one man has many of these long tapeworms at once. But a very instructive little detail is that what escapes from the egg into the water is a microscopic ciliated larva, obviously adapted to finding its way into fishes. The only known exception to the rule that the sexual tapeworms are parasites of backboned or vertebrate animals is the little *Archigetes sieboldii*, a simple unjointed Cestode which completes its whole life within one host, the small river-worm (*Tubifex rivulorum*), a reddish living thread quite common in the mud of streams.

Here it should be noted that man has known for a long time that little transparent sacs occurred in various kinds of flesh which he used as food, and the very ancient laws of some peoples against eating raw flesh, or a particular kind of flesh (such as pig's), or against eating flesh at all, may have been based on some dim awareness of the way in which man became infected with certain parasites. But positive knowledge on the subject is quite modern, for it was not till the nineteenth century that it was proved by direct experiment by von Siebold and others that swallowing a particular kind of bladder-worm was followed by infection with a particular kind of tapeworm. Thus we understand why the bladderworm of the pig had a name, *Cysticercus cellulosae*, all to itself; it was not then known to be the young asexual stage of one of man's tapeworms.

In the life-history of an ordinary tapeworm there does not seem to be any alternation of generations in the strict sense. The bladder-worm develops in a straightforward way from the tapeworm's fertilized egg-cell, and the bladderworm's scolex becomes the tapeworm. In some other cases, however, to which we shall now refer, the life-history is not so simple and is regarded by some zoologists as illustrating alternation of generations.

THE STORY OF THE STURDIE WORM.—One occasionally sees in the country a sheep staggering round in a circle or falling to the ground in convulsions. This means that the sheep is infected with a large bladderworm in its brain—the 'sturdie worm.' The locomotor dis-orders due to this parasite are not to be confused with the commoner sight of a fat and heavy-fleeced sheep lying on its back in a slight depression where it cannot right itself. In this case we should lend a helping hand; in the former case the outsider can do nothing.

The sturdie or 'staggers' worm has a strange life-history. Its host as a tapeworm (*Taenia coenurus*) is the dog, and when a joint passes on to the grass the enshelled embryos may be swallowed by a sheep. The hexacanth larva bores from the sheep's stomach into a blood-vessel and is carried round the body. It seems to come to rest only in the brain and spinal cord. There it swells into a large bladderworm (*Coenurus cerebralis*), often the size of a walnut, and with

the peculiarity that instead of the usual *one* head, it forms many heads. The growth of this large sac, pressing on the sheep's brain, produces the locomotor disorders; or, if the growth is in the spinal cord, there may be paralysis of the fore-limbs or the hind-limbs according to its position. Now if a dog should pick the brain of a sheep that has died of sturdie or been killed because of the parasitism, then it will be infected with a tapeworm for every head. On the other hand, if vigorous measures are taken to purge the dogs and destroy the expelled tapeworms, the spread of the disease will be stopped. The sturdie bladderworm may also occur in cattle, goats, and horses.

In the dog there is another tapeworm, called *Taenia echinococcus*, with a remarkable life-history. It is very small, not longer than half the breadth of one's little finger-nail, and it has only three joints—a fact which prepares one for finding that it has another way of multiplying. When the dog is much about the house, as in a Lapland hut or an Australian ranch, the small proglottis may readily get on to dishes or food and be swallowed by man; or some of the microscopic eggs may be spread about in the same way. The hexacanth set free in man's stomach bores into a blood-vessel, and is carried round the body. It may find anchorage in the liver, which is serious; or in the brain, which is likely to be fatal. For it grows into a bladderworm which may be as large as an orange. This fluid-filled bladderworm has many heads on its wall, but it also sets buds called ' brood-capsules ' free into its interior, and these again produce heads. The difficulty immediately rises in the mind that as the dog does not eat man, the heads within the big bladderworm in man will not get on any further. This is the case. But the large bladderworm is also found in cattle, goats, horses, and some other mammals that swallow the joint or the eggs when eating contaminated grass. Thus the vicious circle continues, yet it might be brought to an end entirely if resolute measures were taken to purge the sheepdogs and burn the expelled tapeworms. In the meantime it should be made impossible for the dogs to get access to the liver, etc., of infected mammals.

Before we leave these unpleasant tapeworms, we must notice that there are some very simple unjointed forms, such as *Ligula*, *Amphiline*, and *Caryophyllaeus*, which have only one set of reproductive organs, and serve in these and other ways to link the ordinary tapeworms back to a Trematode or a Turbellarian ancestry. There is no lack of **connecting-links** in evolution!

PARASITISM IN GENERAL.—When an animal is so intimately associated with another animal, or with a plant, that it cannot live apart from it or some other like it; when it depends entirely on that other creature for shelter and sustenance; when it does not confer any benefit on its so-called host; and when it does not need to exert

itself in any appreciable way to get its food, then we call it a **parasite.** Our reason for this long definition is that there is a tendency to blur the whole idea of parasitism by including within it any living creature that lives in a one-sided association inside or on the surface of another, feeding upon it or on what it affords. This loose use of the word spoils the root-idea that a parasite lives a drifting life of ease, away from the ordinary struggle for existence, and free from the necessity to exert itself in procuring food. An animal like the Trypanosome of sleeping sickness is a parasite in the sense that it finds food and shelter inside an antelope, a tsetse fly, and perhaps a man. But the Trypanosome is a very energetic animal; it is a predatory creature, devouring its host from within. Similarly, the nimble flea is an intermittent beast of prey, with none of the marks of a true parasite like a tapeworm floating in its host's food-canal, or a liver-fluke living on the blood of the liver in which it is embedded. The point is that the word parasite should not be applied to active predatory animals that work hard for their living, though they sojourn habitually in close association with other creatures, either externally or internally. No doubt, however, the various relations fade into one another.

Animal Parasites

(*a*) **External** (*Ectoparasitic*):

On plants, e.g. scale-insects.

On animals, e.g. lice, fish-lice, some flukes.

(*b*) **Internal** (*Endoparasitic*):

In plants, e.g. many threadworms.

In animals, (1) living on digested food in the food-canal, e.g. tapeworms; (2) feeding on living cells, including blood, e.g. liver-fluke, Bilharzia.

SENSITIVENESS TO PARASITIC WORMS.—Infection with parasitic worms may have various evil consequences. Some tapeworms, present in large numbers, absorb a considerable quantity of digested food; some threadworms may perforate the wall of the food-canal and bring on peritonitis; the hookworms cause anaemia by sucking blood from the intestinal wall; the gapes-worms may choke the chicken's windpipe; and so forth. But it has often seemed as if, in addition to all the familiar damage, the exudations of certain parasitic worms had a poisoning or toxic effect on the host. One reason for this suggestion is the undoubted sensitiveness that some people show to cutaneous contact with certain helminthes, such as the *Ascaris* threadworms of horse and of man. Often there is a hypersensitiveness comparable to that which some people show to the pollen that causes

hay-fever, or to even small quantities of particular foods, such as egg. Some interesting experiments have been recently made by F. A. Coventry and W. A. Taliaferro. Protein extracts of Ascaris were made and introduced by scratches into the skin of 130 Honduras patients, with the result that 80 per cent of them showed wheal formation and erythema within twenty minutes. Similarly with 80 per cent of 84 patients tested by the scratch method with hookworm protein extract. So again with 25 per cent of 64 patients tested with *Trichuris* extract. In none of the three sets of experiments was there any correlation between the hypersensitivity and the presence of the relevant parasites within the patients. So the tests have no diagnostic significance. Yet practically all the natives studied were probably infected with Ascaris at some time in their lives, and it is suggested that the hypersensitiveness is correlated with previous infection with the parasites in question. This view is confirmed by the results of precipitin experiments.

PARASITES AND VIGOUR.—In ' Wild Nature,' i.e. nature not greatly affected by human interference, disease is rare, but parasites are common. Yet these parasites are often of little or no importance to their hosts. A live-and-let-live compromise has been established, and many a wild animal has thousands of internal parasites without being appreciably affected.

An interesting light is thrown on this by some recent experiments on lambs by I. C. Ross and N. P. Graham, who find that good nutrition has a very salutary influence on parasitism. In improved pastures the tendency is for heavily infected sheep to throw off their parasites. Thus good nutrition in natural conditions will tend to check the multiplication of parasites. Vigour almost always counts in the struggle for existence.

PEARLS.—This may seem a strange place for the discussion of pearls, but the reason is simple and clear. Some of the best pearls are formed around the larvae of tapeworms or of flukes that have found access to a mollusc, such as the pearl oyster or the freshwater mussel. A pearl is built up of very fine concentric layers of limestone and of an organic substance called **conchin** or **conchiolin**, which helps in the formation of all mollusc shells. Lining the shell of any bivalve there is a fold of skin called the ' mantle,' and this secretes the limestone and the conchin. A pearl is a departure from the usual routine of shell-making.

If a foreign body is intruded between the shell and the mantle, it becomes surrounded by layer after layer of mother-of-pearl. But this can never make a true pearl. One reason is that the centre is likely to be an opaque body like a grain of sand, or a minute spherule of mother-of-pearl introduced by the modern pearl-fisher. Another

reason is that a true pearl is always formed in a sac of the living skin or mantle, quite free from the shell. In this pearl-sac there is some irritant or stimulus that induces the formation of the concentric layers of calcium carbonate embedded in a framework of conchin.

(1) The irritant or stimulus that provokes the pearl-formation may be a dead fragment, such as a grain of sand, and then the pearl is not a good one. (2) But the stimulus may be the very delicate larva of a fluke or a tapeworm, which disappears, leaving a clear centre. This may result in a ' fine ' pearl! Or (3) an excellent pearl may be formed around a little fragment of the living skin engrafted into itself. Or (4) a ' fine ' pearl may arise around a blob of organic matter produced by inflammation or the like. Or (5) there may be no visible centre at all.

So there are pearls and pearls.

CHAPTER VII

ROUND WORMS OR NEMATODES

A separate phylum, with Nematodes as the chief class—Diverse modes of life—General characters—Some life-histories—Some other practically important Round Worms—Latent life—Experiments on Eelworms—Threadworms of the soil—Hookworms in the soil—Transport of Nematodes by flies—Horsehair Worms—Some other ' worms '—The quite unrelated Ribbon-worms or Nemerteans—Red blood.

A SEPARATE PHYLUM, WITH NEMATODES AS THE CHIEF CLASS.—Far away from the flat worms are the round worms, on a different tack altogether. Technically stated, the phylum *Nematohelminthes* is not related to the phylum Platyhelminthes. This brings us back to the difficulty in using the word ' worm,' that it is only a name for an elongated shape. Round worms include (1) hundreds of different kinds of threadworms (**Nematodes** proper, from *nema*, thread); and (2), with a different internal structure, the horsehair worms that come out of insects into wayside pools; and (3) some other rather difficult worms with little resemblance save a cylindrical shape of body. There are at least these three classes in the phylum of Round Worms or *Nematohelminthes*, namely Nematodes, Gordian worms, and *Acanthocephala* with a spiny anterior end.

DIVERSE MODES OF LIFE.—Round worms live in fresh water, in damp earth, in the sea, and inside animals or plants. Many live on rotting material that bacteria have prepared for them, and this way of living is called **saprophytic.** It is difficult to draw a line between the saprophytic round worms that live freely, and some of those that live in the food-canal of higher animals, where the residue of the food is often rotting. And again, how difficult to draw a line between a horse-worm (*Ascaris*) living in the stomach of the horse on the digested or partially digested food and a gapes-worm that sucks blood from the walls of a chicken's windpipe! It cannot be said that Nematodes show much in the way of special fitness for parasitic life, or much of that degeneracy that is usually associated with the parasite's life of ease. Most of these are rather energetic animals, and we venture to call the great majority either saprophytic or predatory. A provisional mapping-out of **Ways of Living** is here attempted.

Chief Ways of Living among Animals

I. **Independent and Individualistic,** pursuing the each-one-for-himself policy, either as beasts of prey, or as herbivores, or as devourers of accumulated organic material. Examples: Fox, Hare, Eagle.

II. **Independent, yet Co-operative,** exhibiting some self-subordination and mutual aid, rising to social organization. Examples: Ants, Bees, Wasps, Rooks, Beavers.

III. **Living with the Help of Partners or Symbionts.** Examples: Radiolarians, Green Hydra, Wood-eating White Ants.

IV. **Living (as saprophytes) on rotting material outside organisms.** Examples: many Nematodes.

V. **True Parasites,** bound up in a one-sided association with other organisms, from which they obtain food almost without exertion. Examples: Tapeworms.

GENERAL CHARACTERS OF ROUND WORMS OR NEMATODES.—The body is all one piece, without the ring-like divisions or segments that an earthworm shows so clearly. Whether big or little, the shape is almost always the same—cylindrical, with a blunt head-end and a tapering tail. Some are delicate threads, others are like pieces of twine. There is rarely any colouring matter (pigment); the body-wall is dull white or translucent. The skin, which is not well developed, is enveloped by a resistant **cuticle,** often thick, often finely striated, often subject to being shed or moulted. This follows from the fact that the cuticle is a non-living, non-cellular outer layer made and re-made by the underlying living skin. Hence it cannot grow when the animal grows, and must therefore be moulted periodically. This is the first instance of **moulting** in the animal kingdom. Below the skin and likewise part of the body-wall is a well-developed mesoderm layer of muscle-cells; and then comes the cavity of the body in which the food-canal lies. It does not quite correspond to the true body-cavity of the earthworm, one reason being that there is no mesoderm swathing the outside of the food-canal. For the first time in the animal kingdom there is a **through-and-through food-canal**; that is to say, the food-canal is a tube open at the two ends—the *mouth* and the *anus*. Round the front end of the food-canal there is a ring of nerve-cells, from which delicate nerves extend to the anterior tip of the worm and also in the opposite direction. But there is no brain in the strict sense and very little in the way of sensory structures. There is no blood system or breathing system. Along each side there runs an excretory vessel which collects fluid waste and gets rid of it anteriorly at a single pore. The sexes are usually separate and the reproductive organs simple. The eggs are fertilized in the female ducts and the sperms are unusual in being sluggish and amoeboid. The male is usually the smaller, sometimes much smaller, and is often provided with structures, such as spines, which make it easier to transfer the sperms into the female. Unless it be some lash-like

motile processes which sometimes move the sluggish sperms into contact with the eggs in the female duct, there are no cilia or flagella in Nematodes; and another remarkable fact is the absence of migratory amoeboid cells or phagocytes. These wandering cells seem to occur from Sponges to Man, *except* in Nematodes and Lancelets. In Nematodes there may be *fixed* phagocytes in connection with the excretory system. The life-history of Round Worms is often intricate.

SOME LIFE-HISTORIES.—Many people are repelled by threadworms or Nematodes, but their life-histories are certainly interesting. Let us take some examples.

(*a*) The maw-worm (*Ascaris lumbricoides*) is a large parasite in the human intestine, especially in children. It is not usually dangerous, but it is troublesome, for it may be as large as an earthworm. *Lumbricus* is the name of a common kind of earthworm, and if we translate *Ascaris lumbricoides* into English, it means ' the jumper that is like an earthworm.' The word ' jumper' or Ascaris refers to the creature's vigorous muscular movements. How could we distinguish it from an earthworm? It is not a ringed worm; it is dull white, not reddish; the skin is much tougher; the head end is blunter than the posterior end; in fact, though it is called *lumbricoides*, it is not very like *Lumbricus*. Infection is due to swallowing the microscopic eggs along with raw vegetable food or fruit that has been lying on the ground. The eggs pass out from man's intestine.

On the roadway one sometimes sees a still larger kind of Ascaris, the threadworm of the horse, sometimes a foot long. It has been passed from the intestine of the horse, which is infected by drinking stagnant water. There is a very common minute threadworm in man's food-canal, called the pin-worm (*Oxyuris vermicularis*), which seems to be introduced along with raw vegetable food, such as radishes, or with polluted water. Of similar history is another very common Nematode in man, the whip-worm, like a miniature carriage-whip.

(*b*) The most serious of the Nematodes, as far as man is concerned, are the hookworms (*Ankylostomum* and *Necator*). In warm countries in many parts of the world they cause bloodlessness, depression, and a terrible lowering of vitality. No heavier mundane cloud has ever rested on the human race, for natives who are badly infected become utterly dispirited and enfeebled. The worms are sucking blood from the walls of the intestine into which they burrow, destroying the capillary branches of the blood-vessels. The developing eggs pass into the soil and larvae are hatched out. These cannot move about much, but they may be carried on the feet of animals, and they remain for a considerable time able to infect man. This they do in most cases by entering the skin of bare feet by minute cracks and the like. Having entered, they find their way to the food-canal.

By doses of various kinds, it is not difficult to expel all the hookworms from a man, and reinfection may be prevented if the soil is not contaminated in a wholesale way around the village or camp. In some places the percentage of cases has been reduced in a very remarkable way by taking simple sanitary precautions. Infection occurred abundantly and fatally among the workmen who made the St. Gothard tunnel, and it has repeatedly occurred in similar conditions. It is readily intelligible that when the soil is contaminated with larvae, there is likelihood of infection amongst those who are much in contact with it, especially if they have little cuts on their hands or feet. An American kind of hookworm is called *Necator*.

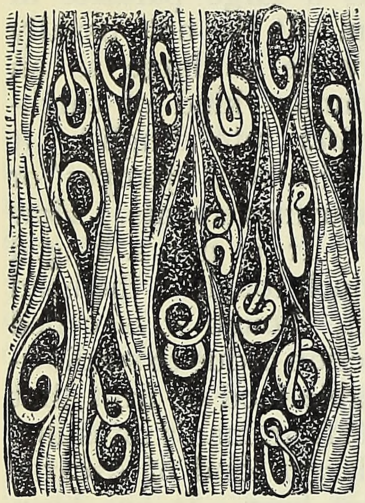


FIG. 57. *Trichinellae* IN MUSCLE.—After Leuckart

(*c*) The guinea-worm (*Filaria medinensis*), of Egypt, Arabia, and further east, causes ugly sores in man's skin, and is regarded by some as the 'fiery serpent' that troubled the Israelites on their desert journey. It has a remarkable life-history. The larva occurs in a very common minute crustacean or water-flea, called *Cyclops*, and finds its way into man along with polluted water. In man's body it develops into a long female worm, like thin twine, which moves about to some extent, but often settles down and coils up beneath the skin, especially of the back and legs. It varies from one to six feet in length, and a sore is apt to form, especially if there is pressure on the place where the worm lies. An old method of dealing with this troublesome intruder was to get part of the body round a piece of stick like a lead-pencil, and slowly unwind it day after day. The modern method is to keep the infected part of the body moist, and then the female emerges, for she is seeking water in which to liberate her eggs. The minute male has been rarely seen.

(*d*) Another kind of life-history is illustrated by *Trichinella spiralis*, a parasite of rat, pig, and man. The adults live in the intestine, the female about an eighth of an inch long, the male about half that length. After pairing, the female gives rise in the wall of the intestine to numerous (about 1,500) very minute larvae, which are hatched inside the mother. They get into their host's circulation and find their way to the muscles, sometimes doing a little boring on their own account. In the muscle-fibres, say of a rat, they coil themselves up, spoiling the fibres, and lie dormant, sometimes in thousands, each within a firm envelope or cyst. They cannot be seen except with a microscope. If a pig eats the 'trichinosed' rat, the larvae

are set free from their cysts and become in a few days reproductive. They feed, grow, moult, and pair. The males seem to die; the females give rise to many larvae; and then there is the migration. If the 'trichinosed' pig's flesh is eaten by man, the story repeats itself. The encysted larvae can remain alive for many years. In Britain the disease is practically unknown; on the Continent it is becoming less frequent.

SOME OTHER PRACTICALLY IMPORTANT ROUND WORMS.—One of the strangest of the round worms or Nematodes is the forked worm or red worm, *Syngamus trichealis* (*syn*, together; *gamos*, coupling; *trachealis*, in the trachea or windpipe), which causes 'gapes' in turkey and various game-birds, and is common in young chicks. It is strange because at an early stage the male becomes attached to the female, adhering to the opening of the genital duct, so that the two are almost as one, like a letter Y with a long snaky stalk. It is strange in being red, for few Nematodes have any pigment, but the redness is due to the chick's blood shining through the worm's skin. It is rather strange, furthermore, in the way the female clinches its mouth-armature in the wall of the windpipe of its host. As to the life-history, what usually happens is that the chick coughs up the paired worms and that the female (about an inch long) bursts on the ground, setting free developing eggs. The chicks are infected by picking up the microscopic developing ova or embryos, or by swallowing the red worm as a whole, or by eating an earthworm which has the developing embryos in its food-canal. Infection may persist in the soil for a long time; eggs and larvae have been kept alive in moist media for over eight months at a temperature of about 50° F. When eggs with embryos inside are given to young chickens, the young worms may be found in the lungs within a week. The two sexes are coupled in the lungs while still only one-tenth of an inch long; they move forward into the windpipe; the female becomes mature in about two weeks after the eggs were swallowed by the chick. Every one knows the value of securing clean water and a change of run, and of avoiding damp soil, for in this the larvae of the gapes-worm thrive. Many people are familiar with the sight of young chicks running about with their mouth agape, as if they would choke, as they sometimes do. It is occasionally possible to dislodge the gapes-worm from the windpipe by inserting a feather dipped in turpentine.

Many 'palisade-worms' or *Strongyles* are parasites of domesticated animals. A small Filaria is sometimes seen under the cornea of a horse's eye. The blood-filaria that lives in the lymphatic glands (see INDEX) and blood of man in warm countries, causing for instance a strange thickening and coarsening of the skin, passes its larval stage in a mosquito, by whose bite it is introduced into man. Sometimes

seen in moist soil in the garden are brownish hair-like worms, such as *Mermis*, which come out of insects, such as grasshoppers and caterpillars, when mature; they are not to be confused with horse-hair worms. A very peculiar Nematode called *Sphaerularia* lies inside humble-bees.

Another remarkable form, *Ichthyonema* (*ichthys*, fish; *nema*, thread), is found coiled up in the body-cavity of sea-urchins—a strange habitat. It has the thickness of parcel twine, and may be several feet in length. Plants are attacked by a multitude of Nematodes, such as species of *Tylenchus* in cereals, and species of *Heterodera* in root-crops like turnips and radishes.

LATENT LIFE.—Many small threadworms are able to remain dry for years without dying. This is well illustrated by **paste eels** (*Anguillula tritici*) which sometimes swarm in forgotten saucers of paste, and **vinegar eels** (*Anguillula aceti*) which often swarm in vinegar cruets that have been left unstoppered. Another good example, which we have personally studied a little, is a minute threadworm (*Tylenchus hordei*) that forms **root-galls** on the sand-binding grass. In these cases the body becomes dry and brittle; there is no sign of life at all; yet when they are restored to damp surroundings they become once more active. It has been recorded that Anguillulas may exhibit this **revivification** after being in a state of latent life for fourteen years. The chemical molecules of the living matter have ceased to change, and yet they have not broken up. The state may be compared to a frozen stream, or to a clock which has stopped though not run down. But no one understands with any exactness what happens when a paste eel passes into this state of **desiccation.**

EXPERIMENTS ON EELWORMS.—The threadworm, *Tylenchus tritici*, that causes 'ear-cockles' in wheat, is famous for its power of surviving prolonged desiccation. In its brown or purple galls which replace the grains of corn there are hundreds of motionless larvae, the progeny of a pair. They can remain for a long time inert, yet not dead. When the galls are soaked in water for some hours they swell up and liberate a creamy substance, which is made up of crowds of minute larvae. They can wriggle and they can swim, and the importance of this is that they can reach and infect wheat seedlings if galls have been sown along with the healthy seed. The question recently reinvestigated by Dr. T. Goodey is how long the desiccation may last without being fatal. Needham sent some galls to Baker in 1744 and it was believed that revival took place in 1771. It seems, however, that no adequate proof of the vitality of the larvae was given. No mention is made of their movements. It is of much interest, therefore, to note that in Dr. Goodey's recent experiments with the wheat eelworm the maximum period of non-fatal desiccation

was nine years. In an allied species, *Tylenchus dipsaci*, found in diseased onions and narcissus bulbs, the almost mature larvae revived after being kept dry for two years and two and a quarter years respectively. The period of possible reviviscence or coming alive again probably varies according to conditions, and more experiments should be made, for the state of latent life certainly deserves more penetrating study.

We may bring together some other instances of similar states of suspended activity. (*a*) From normal rest and sleep, there is an inclined plane to faints, coma, and trance. (*b*) On a line by itself is the hibernation of some mammals, such as hedgehog, dormouse, and bat. (*c*) Quite distinct is the winter lethargy of sundry cold-blooded animals, such as some snakes, lizards, and tortoises, frogs and fishes, not to speak of sealed-up snails, dormant queen humble-bees, and lower animals still. This is a long way from latent life, for the heart is slowly beating and the blood sluggishly circulating, though in various degrees in different types. (*d*) The inactivity is deeper in cases where the resting organism is not the fully formed adult, but some younger stage in an externally quiescent phase of slow internal reconstruction. Thus the resting chrysalid, undergoing the great change towards becoming a moth, is rather different from the comatose queen humble-bee or queen wasp. (*e*) The inertness is deeper in seeds sown in the ground, though processes of fermentation may be going on, which is not the case with the dry seeds in the seedsman's shop. (*f*) A lower level is that of enshelled eggs, encysted amoebae and the like, a state of latent life without activity, but one in which the living matter remains fluid. (*g*) The lowest level, we think, is that of *dry* latent life, as illustrated by some Nematodes, water-fleas, rotifers or wheel animalcules, mites, and tardigrades or water-bears (see INDEX). Here we have to face the difficulty that the living matter has ceased to be fluid; it has passed out of its normal **colloidal** state, that is to say a fluid in which multitudinous ultra-microscopic particles or droplets are suspended mobilely. When a seed or an animal dries up gradually in natural conditions it probably never ceases to contain a minute quantity of water, though it must be very little when the tissues become brittle. But perhaps there is always this minute trace of water, till the limit of desiccation is reached. It is said that dried-up paste eels and vinegar eels, which we have mentioned as two species of *Anguillula* (meaning *little Anguilla* or little eel), can revive after fourteen years, but that seems to be the limit. This may mean that the last vestige of water has then disappeared, and the molecules of the living matter begin to break down. In any case, some living creatures have a remarkable power of lying low for a long time.

THREADWORMS OF THE SOIL.—There is great variety in the mode of life among threadworms or Nematodes. Some are parasitic in animals, like the threadworm of the horse's intestine, or the gapes-worm of poultry, or the *Trichinella* of rat, pig, and man. Some are parasitic in plants, like the one that causes 'ear-cockles' in corn, or those that cause 'beet-sickness,' 'clover-sickness,' and so on. Others, again, live in rotting substances like manure and mouldy paste, or in fluids that have gone bad, as in the case of the vinegar eel. But others live in clean water, and are sometimes so abundant that they give it a peculiar taste! A few are known from the sea, especially among the seaweeds of the shore. Many parasitic thread-worms spend part of their life, usually their early youth, in the soil, but there is a large contingent very imperfectly known that lives there permanently. Not in *any* kind of soil, but usually where there is a considerable quantity of decaying vegetable matter or animal refuse. They seem themselves to be very indifferent to bacteria. They have a tough constitution.

The threadworms of the soil are very like one another—delicate, translucent or whitish threads, well deserving their name. They show no hint of rings such as are seen on some minute relatives of the earth-worm that are often to be found in damp soil where there is abundant vegetable mould. Many of the soil Nematodes feed on decaying organic particles, and others on the sap of plants into which they bore, but there is a third contingent that has carnivorous habits. In the food-canal of representatives of the genera *Mononchus*, *Tripyla*, and *Trilobus* there are found remains of wheel animalcules or Rotifers, bear animalcules or Tardigrades, bristles of earthworms, and traces of other Nematodes. The interest of the last item is obvious. There are threadworms in the soil that devour other Nematodes, *some of which are injurious to root-crops*.

The carnivorous soil Nematodes are strong and agile forms; and they have been watched under the microscope, attacking and over-coming other threadworms. It is easy to study living Nematodes a little in a watch-glass of water placed under the microscope; their movements are lively and vigorous. The difficulty begins when we try to find out what particular Nematode we are looking at; for the specific characters are mostly minute.

HOOKWORMS IN THE SOIL.—We have already remarked that hook-worm parasites are the cause of one of the heaviest mundane clouds that have ever darkened man's sky. They cause anaemia, wasting, apathy, despair, crippling, death. The minute threadworms, living in moist soil in warm countries, make their way through the skin of bare feet or legs, are carried in the blood-stream to the lungs, and pass thence to the small intestine where they fix themselves to the

walls and draw blood. The eggs pass out from the mature worms and hatch in the soil. So the circle recommences. It is easy by means of carbon tetrachloride or the like to expel the worms from man; but reinfestation is very apt to occur unless the natives will learn to use the latrines provided. In many places the bare-footed children get infected, and this may be prevented by wearing shoes. The larval worms like a loose sandy soil in which they can move about readily and find the indispensable moisture. In close-textured soil, like clay, they cannot thrive. So that there is a correlation with soil as well as with shoes. In Florida the soil and the climate are almost uniformly favourable to hookworms, but the actual amount of infestation varies directly with prosperity; for that means better sanitation and fewer bare feet. The interesting question arises as to the dissemination of hookworms apart from man, and in this connection the rôle of chickens and pigs has been studied. While the eggs and young larvae of the hookworm *may* pass through the chicken's food-canal without being injured, this is not always the case; and it is concluded that chickens do more good than harm in this connection. But as to the free-ranging pig, the conclusion is that it plays an important part in dissemination of hookworm eggs with which man has polluted the soil. Moreover, the pig has a species of hookworm all its own.

TRANSPORT OF NEMATODES BY FLIES.—Many of the threadworms or Nematodes do much harm, and everything that bears on their distribution is of interest. It has been shown that the larvae of the common *Rhabditis* may be carried from one place to another on the bodies of flies, and Menzel has recently tested this. He found some bat's dung to be swarming with threadworms and also with larval *Diptera* (flies). When flies emerged in the course of time he carefully examined them, and found that their legs showed little white spots. One of these, moistened in water, yielded forty Rhabditis larvae. Two house-flies were placed on the dung and in a very short time some of the larval Nematodes had effected fixation. They are carried about till the fly settles on another suitable place, and they can survive being dry for two days or more. Here, then, is another instance of the linking of lives together—bat, fly, and threadworm.

HORSEHAIR WORMS.—In a wayside pool one sometimes finds large numbers of worms, greyish, brownish, or black in colour, like hairs from a horse's tail, but rather stouter. They are often six inches in length, and may be tied up together in a writhing tangle. They are called horsehair worms, and for many centuries there has lingered the superstition that they arise from horse-hairs that have fallen into the water. One day the pool has none, and next day a score; that is the puzzle; and the explanation is that the full-grown worms creep out of the bodies of insects, such as crickets, grasshoppers,

and beetles, that have come to the water. The worms have lived for some months inside their insect host, feeding, growing, and moulting; and when they are full-grown they take up a position with their head close to the surface, ready to creep out if the insect enters the water to bathe or lingers by the side of the pool for some reason or other. When they emerge the worms pair and soon die, but not before the female has twisted white strings of eggs among the water-weed. These eggs give rise to minute transparent larvae which cut themselves free with an armed proboscis and swim about in the water, searching in a dullish way for some animal to bore into. Sometimes they get into a wrong kind of host, and then they die; sometimes they get into appropriate insects such as beetles, and then they thrive and feed and grow. They must absorb their food, like tapeworms, through their skin, for the gullet seems to be blocked and the mouth is either absent or the merest pin-prick of an aperture. In some cases the free-swimming larva that we spoke of enters the aquatic stage of an alder-fly, a may-fly, or a harlequin-fly, and does not complete its life-history until this first host is devoured by a second, such as a carnivorous beetle. One of the common horsehair worms or Gordian worms is called *Gordius aquaticus*, the name referring to the 'Gordian knot' in which the adults sometimes tie themselves. *Nectonema* is interesting as the only horsehair worm found in the sea. The reason why we cannot rank them with ordinary threadworms is simply that their internal structure is very different.

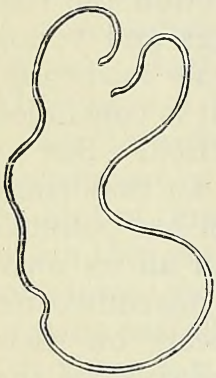


FIG. 58. THE HORSEHAIR WORM (*Gordius aquaticus*)

SOME OTHER 'WORMS.'—There is the same difficulty in classifying some other kinds of worms, such as those parasites for which there has been made a special class, *Acanthocephala*. They look rather like threadworms, but they have no mouth nor food-canal, and the front end of the body bears a protrusible hooked proboscis which is used in boring into the wall of the food-canal of the host in which they live. Hence the name of the class, **Acanthocephala** (*acantha*, thorn; *cephala*, head), and the name of the commonest genus, *Echinorhynchus* (*echino*, spine; *rhynchus*, proboscis). The young stages live in jointed-footed animals such as freshwater crustaceans (*Gammarus* and *Asellus*) and larval insects; the adults in backboned animals, such as pike and perch, trout and minnow, rat and pig.

THE QUITE UNRELATED RIBBON-WORMS OR NEMERTEANS.—The ribbon-worms form a well-defined class, almost all marine, a few in fresh water and damp earth. They vary greatly in size from under an inch to twelve feet or more, with a considerable resemblance to

pieces of elastic band. They are very muscular, and they break very readily into pieces, from each of which a whole can sometimes be regrown. The colours are often bright and the surface of the body is covered with cilia. There are two remarkable ciliated slits on the head. There is a distinct brain. There is a through-and-through food-canal, and an eversible thread-like proboscis lies dorsally in a special sheath of its own, opening above, or, in a few cases, within the mouth. It is bathed in irritating fluid and carries sharp stilets or adhesive papillae. It must be a weapon or a food-lassoing or a probing organ. Sometimes it is shot out with such force that it breaks off and wriggles away, like a worm itself! Most, if not all, of the Nemerteans are carnivorous. Very noteworthy is the first occurrence of *a closed blood system*, and in some forms there is the same red-blood pigment (**haemoglobin**) as in backboned animals. There are flame-cells connected with the excretory system, and this is regarded by some zoologists as a sure sign of the relationship of ribbon-worms to Turbellarians. The sexes are usually separate, and what comes out of the egg is either a miniature of the adult (**direct development**) or a somewhat helmet-shaped transparent larva, adapted for Open-Sea life (**indirect development**). Nemerteans may serve to illustrate what is characteristic of many kinds of living creatures—the exploring of all sorts of habitats. Thus *Pelagonemertes* and *Hyalonemertes* are glassy leaf-like forms that live in the Open Sea; a few shelter inside bivalves; a few frequent freshwater and terrestrial haunts; most move about delicately in the sea-mud, among seaweeds, under flat stones; *Cephalothrix galatheae* destroys the eggs of its host, the beautiful crustacean known as *Galathea*. Life is characteristically insurgent, leaving no alternative untried.

If we rank the *Nemertea* or ribbon-worms as lower in the scale than Nematodes or threadworms, then they were the first animals to have a through-and-through open food-canal, that is, with mouth and anus. They are certainly the first animals to have a closed blood system (or vascular system), and some of them have red blood. Thus we must regard the ribbon-worms as in several respects *pioneers*.

RED BLOOD.—One of the great steps in organic evolution was the gaining of red blood, the importance of the gain being that the red pigment has a strong affinity for oxygen. Its appearance increased the animal's power of capturing oxygen, and it is oxygen that keeps the fire of life burning. Many chemical processes go on in the living body, but combustion or oxidation is *always* going on;[1] that is to say, oxygen is always entering into union with the carbon of carbon-

[1] Some animals are anaërobic, i.e. they can live only in the absence of free oxygen. In such animals (e.g. *Ascaris*) energy is obtained by intramolecular oxidation, i.e. the oxidation of one part of a molecule at the expense of the rest.

compounds, with the result that energy is liberated, work is done, and carbon dioxide is formed as a waste-product. The important red pigment is called **haemoglobin** (see ANIMAL PIGMENTS), whose first appearance we notice in ribbon-worms. It is not common in backboneless animals; it is characteristic of backboned animals. Let us consider it for a little from a chemical point of view. Its molecule or smallest-acting-unit consists (*a*) of a colourless portion, a protein called *globin*, varying in composition in different animals, and (*b*) a coloured portion, called *haematin*, which consists roughly of four 'pyrrol rings' linked with an atom of iron. This is rather interesting because in the molecule of **chlorophyll**, the characteristic pigment of plants, there are also four 'pyrrol rings,' though here they are joined together with an atom of magnesium. A 'pyrrol ring' consists essentially of four atoms of carbon united with one of nitrogen. So there is a deep resemblance between the characteristic plant pigment (chlorophyll) and a very characteristic animal pigment (haemoglobin). But the uses of the two seem quite different, for chlorophyll is a light-absorber and haemoglobin is an oxygen capturer and transporter. It enters into a loose union with oxygen, becoming oxyhaemoglobin; it surrenders this oxygen to the living tissues, becoming haemoglobin again. This is obviously a very important function—to capture oxygen at the surface, whether of skin, gills, or lungs, and transport it to the place of consumption, namely the living tissues. Therefore the question naturally arises: How do animals live that have no red pigment? The first part of the answer is that in many of the simpler animals, without blood at all, the surrounding water penetrates through the body, as in sponge and jellyfish, and brings in with it the indispensable oxygen. The second part of the answer is that there are several **other respiratory pigments** besides the red haemoglobin, which are effective, though not so effective, as oxygen capturers. Thus a very common one among backboneless animals, such as crustaceans, is the faintly bluish **haemocyanin**, where the molecule has a copper atom instead of the iron atom of haemoglobin.

CHAPTER VIII

THE HIGHER WORMS

The Ringed Worms or Annelids — Earthworms — The Earthworm's colour — Reflex actions — Agricultural importance of Earthworms — Freshwater Worms — Ringed Sea-worms or Polychaetes — Tube-inhabiting Worms — Palolo-worms — Echiurids — Primitive Worms — *Myzostomum*.

THE RINGED WORMS OR ANNELIDS.—The higher worms include the earthworms which are familiar to all, the freshwater worms which are not much noticed—little reddish threads in the mud of streams, and the sea-worms, as beautiful as they are numerous, often with paddle-feet and iridescent bristles, often living in tubes. Then there are the leeches, a well-defined class, chiefly at home in fresh water, but also found in damp places, and in the sea. Excepting tape-worms, which usually bud off a long chain of joints, the lower worms are unjointed, that is to say, the body is all of one piece. But a great step was made when the body became what we see in earth-worms, a succession of rings or **segments.** It opened the way to greater division of labour in the body, especially when the rings began to develop **paired limbs or appendages,** such as many of the sea-worms show. Another step in advance is marked by the growing importance of the head, which often carries tentacles and feelers. A new plan of nervous system is seen—the **annulate type of nervous system.** It consists of a dorsal brain (two cerebral nerve-centres or ganglia), a ventral chain of ganglia, and a ring round the gullet connecting the two. This plan of nervous system is found not only in the ringed worms but in the jointed-footed animals such as crustaceans and insects.

Another important step is marked by the establishment of a **body-cavity** or **coelom**, that is to say, a space between the body-wall and the food-canal. It is the cavity into which one cuts in dissecting an earthworm or ' gutting ' a fish. In mammals it is divided into the chest-cavity (with heart and lungs) and the abdominal cavity (with stomach, intestine, liver, and other viscera). The establishment of a body-cavity implies the appearance of a much more definite body-wall, consisting not only of the ectodermic or outer skin (the *epidermis*), but of the mesodermic or inner skin (the *dermis*). In ringed worms the dermis is represented by muscle-fibres, usually arranged like the hoops and staves of a barrel, circular to the outside, longitudinal to

the inside. The body-cavity is lined by the middle layer of cells—the mesoderm, and it often contains a fluid with floating corpuscles like those of the blood. While a typical body-cavity is quite separate from the blood system, it had at first a somewhat similar use as a reservoir for a common fluid that bathes all or most of the organs. The reproductive organs usually develop on the internal wall of the body-cavity, and another feature is that, in its earlier forms at least,

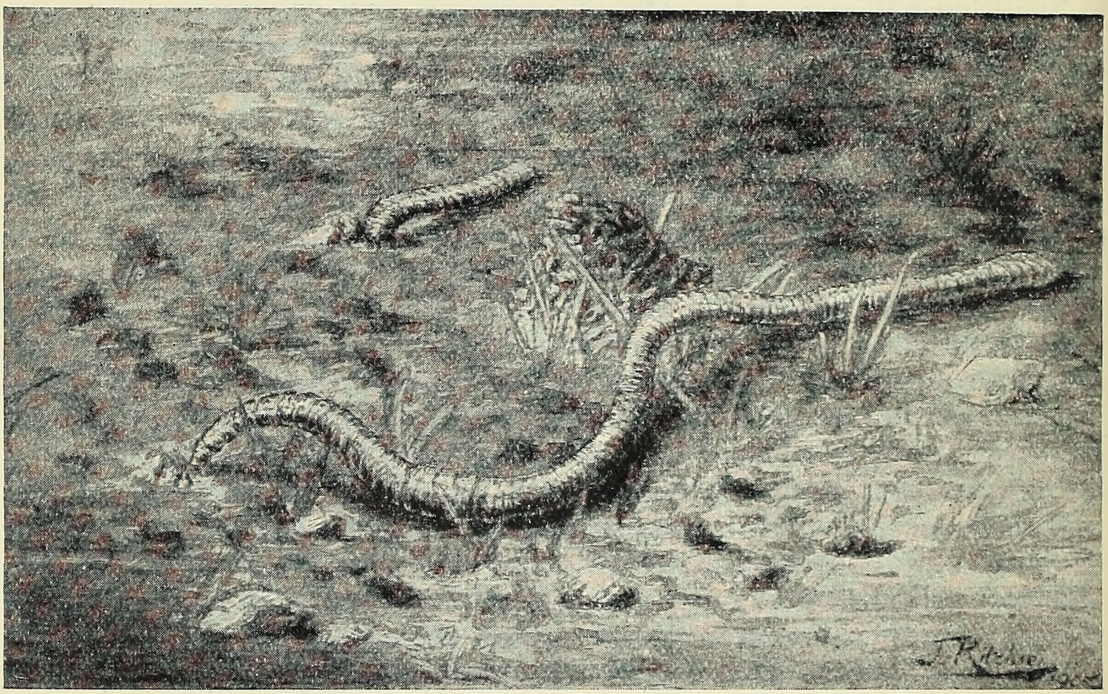


Fig. 59. Earthworms

the cavity is put into communication with the exterior by means of **kidney-tubes** or **nephridia** (diminutive of *nephros*, a kidney), which sometimes serve as the ducts by which the egg-cells and the sperm-cells find their way to the exterior. A typical kidney-tube or nephridium is a twisted tube opening to the outside and with an internal ciliated aperture that communicates with the body-cavity or with some part of it. Microscopic particles can be wafted from the body-cavity into the internal ciliated aperture of the nephridium, and thence to the outside; but there is a finer kind of filtering by which fluid nitrogenous waste-products pass into the nephridium from the blood-vessels spread out on its walls. Nephridia represent little kidneys, and an animal like an earthworm may have a hundred pairs of them in a row along each side of the body-cavity. A very interesting fact is that in the embryos of all backboned animals, from fishes to man, there is a double row of kidney-tubes (or nephridia), some of which

eventually become compacted to form the two kidneys. So that in this respect one might say that the higher animals begin where the worms leave off. This is a somewhat technical matter, but it is of great importance; and, to avoid inaccurate simplicity, we must notice that some animals have tubes (**coelomoducts**) opening from the body-cavity to the exterior, which have not the same structure or develop-

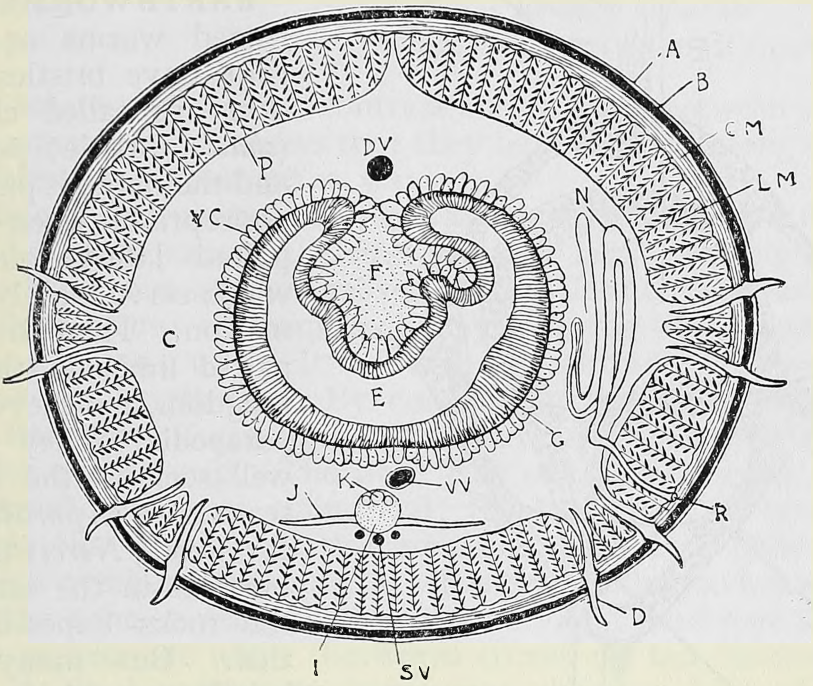


Fig. 60. Transverse Section of Earthworm

A, cuticle; B, epidermis; CM, circular muscles; LM, longitudinal muscles; D, a seta; C, coelom; YC, yellow cells; F, typhlosole; VV, supra-neural blood-vessel; SV, sub-neural blood-vessel; DV, dorsal blood-vessel; P, peritoneum; E, cavity of gut; G, endodermic lining of gut; N, part of a nephridium; R, opening of a nephridium; I, the nerve-cord; J, a nerve given off; K, giant fibres in the nerve-cord.

ment as nephridia. The development of an earthworm or a leech is *direct*; that is to say, what comes out of the egg-envelope is a miniature of the adult. But the development of most sea-worms is *indirect*; that is to say, what is hatched out is a free-swimming larva, entirely unlike a worm. The commonest larva is a **trochosphere.** It is like a transparent microscopic top and swims freely by means of a ring of cilia in front of the mouth (see Fig. 61). At the anterior tip of the trochosphere there is a cluster of nerve-cells, called the ' apical spot.' A simple food-canal twists through the body, and between the outer layer and the gut there appear primitive middle-layer cells (**mesoblasts**) which form, for instance, a first pair of kidney-tubes and the beginning of muscles. The free-swimming larva corresponds

mainly to the head-end of the future worm, and the numerous rings are developed by a growing and segmenting of the posterior part where the point of the top would be. As this elongates there is usually a change of habit and habitat; the young worm sinks to the sea-floor and becomes less energetic.

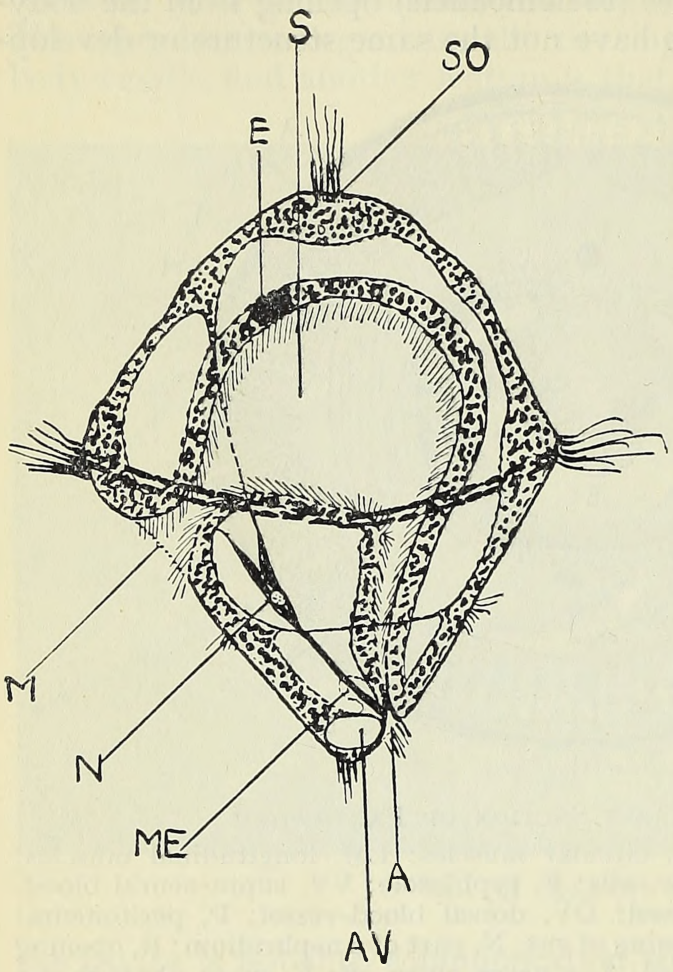


FIG. 61. A TROCHOSPHERE LARVA. After Shearer

M, mouth; A, anus; S, stomach; N, larval kidney; SO, apical sense-organ; E, eye-spot; ME, beginning of mesoderm; AV, anal vesicle.

EARTHWORMS.—Those ringed worms or annelids that have bristles in their skin are called **chaetopods** (*chaeto*, bristle; *pod*, foot); and the name is particularly appropriate when there are paired lateral outgrowths, which serve mainly for locomotion. These are the **first paired limbs** in the animal kingdom, and they are called **parapodia.** They are very well seen in the iridescent sea-mouse (*Aphrodite*), or in the strong *Nereis* that often burrows in the sand beside the rocks exposed at low tide. But many of the bristle-worms have no 'feet' or parapodia and only a relatively small number of bristles. They form the order of earthworms and freshwater worms, and they are called **Oligochaeta** (*oligo*, few; *chaeta*, bristles), in contrast to the sea-worms or **Polychaeta** (*poly*, many; *chaeta*, bristles). The contrast goes very deep in structure, habit, habitat, and development; and it may be useful to state it in parallel columns:

Oligochaeta (Earthworms and Freshwater Worms)	**Polychaeta** (Ringed Sea-worms)
Relatively few bristles.	*Many bristles.*
No parapodia.	*Parapodia.*
No 'jaw' apparatus.	*Often with 'jaws' in the pharynx.*

Oligochaeta (Earthworms and Freshwater Worms)	**Polychaeta** (Ringed Seaworms)
The head less developed.	*The head usually more developed.*
No tentacles or cirri.	*Often with tentacles and tactile feelers (cirri).*
Rarely with gills.	*Gills often present.*
Hermaphrodite.	*Sexes usually separate.*
Development direct.	*Development in most cases indirect.*

It is of interest to make a contrast such as this between two allied orders of animals, for it shows that they have evolved along divergent lines, different in a great many ways.

An ordinary earthworm has often about a hundred and fifty rings in its body, each (except the first and the last) with eight bristles fitted into little skin-sacs and moved by muscles at their base. There are four double rows of them, and they give the worm a grip of the soil so that it can pull itself forward, by contracting those muscle-fibres that run lengthwise. By contracting the other muscle-fibres that run hoopwise, it can narrow its body, and thus force part of it forward for a fresh grip. The front part of the earthworm's body is more pointed and more cylindrical; the hind part is broader and flatter. At the very tip of the front end there is a little sensitive hood, which overhangs the mouth. Posteriorly the food-canal has its opening (the **anus** or vent) right at the very end; and here the 'castings' are passed out when the worm comes up tail foremost in its burrow. A dead earthworm sometimes shows a hint of rainbow colours or iridescence. This is due to the way in which the light-rays are broken up in falling on a finely cross-hatched surface, which in this case is the delicate outermost layer of the skin—the **cuticle.** If a little piece is stripped off and examined under the microscope in a drop of water it will be seen to be quite transparent, but it is crossed by innumerable fine lines intersecting at right angles, and this forms the 'grating' that causes the colour. This is a simple instance of purely **physical** or **structural colouring,** for there is obviously no pigment in the transparent cuticle. On the other hand, the earthworm's red blood gives some colour to the skin, which contains minute blood-vessels, just as in our own case, and this illustrates **pigmentary** or **chemical colouring,** for there is a definite pigmentary substance, namely haemoglobin. There is no life in the earthworm's cuticle, nor in any true cuticle, which may be defined, therefore, as an external layer, not in itself living or cellular, but made (and often remade after moulting) by the underlying living skin—the epidermis. The shell of a crab or the shard of a beetle may serve to illustrate a firmer kind of non-living cuticle.

THE EARTHWORM'S COLOUR.—Things are seldom so simple as they seem, and this may be illustrated in reference to the familiar redness of earthworms. What makes an earthworm red? Is it always blushing? Or is the skin so thin that the red blood shines through? And is there any use in its being red? It seems to have been securely established that the earthworm has in its blood the same red pigment, haemoglobin, as we and all backboned animals have. But the red blood pigment in the earthworm is in the fluid of the blood, whereas in backboned animals it is in the red blood corpuscles. This is an unimportant difference, however; for the earthworm and for man the physiological significance of the haemoglobin is the same, it captures oxygen from the outer world—on the earthworm's skin, on the lining of our lungs—and surrenders it again to the tissues, where it is required to sustain the vital combustion that living implies.

But the redness of the earthworm's skin is not directly due to haemoglobin; it is due to another pigment called *porphyrin*. And this requires just a word of explanation. Haemoglobin (p. 142) is a combination of an iron-containing brownish pigment called *haematin* and a white-of-egg-like or protein substance called *globin*. But if the haematin in the blood be treated with sulphuric acid, the iron is filched away to make ferrous sulphate, and a pigment called *haematoporphyrin* is left. This pigment is also formed in the course of the everyday chemical routine of many animals, and it is not very unfamiliar, because there are traces of it in normal urine, and quantities of it in some kinds of abnormal urine. Well, to come to the point, the pigment in an earthworm's skin is a porphyrin, but Kobayashi has recently shown that it is different from haematoporphyrin. It is, in fact, nearer to a porphyrin that can be derived from chlorophyll, the green pigment of plants. It is possible, then, that the redness of the earthworm's skin comes, not from the haemoglobin of the blood, but from the chlorophyll in the decaying vegetable matter on which the earthworm feeds. A porphyrin of this origin may be absorbed from the earthworm's food-canal by the blood, and then deposited in the skin. This may seem much ado about nothing, but it is a fresh illustration of the danger of thinking of things too simply. As to the use of the porphyrin in the earthworm race, it probably protects the earthworm from the injurious effects of light, to which it is extraordinarily susceptible. This leads our thoughts to the origin of the earthworm's subterranean and nocturnal habits.

About thirty rings from the head-end of a full-grown earthworm the skin begins to be much swollen. It contains numerous active **gland-cells**, that is to say, cells that make an organic **secretion** at the expense of their living matter. This secretion oozes out on the surface and is somewhat glue-like; it helps to bind two earthworms together

when they couple (that is, come together sexually in pairs); and it also makes a barrel of slime that hardens round the eggs and forms a **cocoon.** An earthworm's cocoon is rather different from an egg-shell; it is a bag or an envelope containing *several* eggs, or, it may be, several young worms. The spider's cocoon is a silken bag containing the eggs or the newly hatched young ones. It is a pity that the same word ' cocoon ' is used in a different way for the sheath that is formed round a larval insect when it is about to undergo its great change into a winged adult. This kind of cocoon may be silken or papery or earthen, and so forth. (See LIFE-HISTORIES OF INSECTS.)

The earthworm's food-canal is interesting. Behind the mouth there is a muscular pharynx which swallows the earth and helps the mouth to grip leaves and small pebbles. This is followed by a gullet, and this by the crop and gizzard. The crop is a sort of hopper to the gizzard mill, and in the strong-walled gizzard the soil is ground to finer powder. The rest of the food-canal is the yellow intestine in which the vegetable matter of the soil is digested and the results absorbed. The soil is not in itself of much, if any, nutritive value to the earthworm; the food consists of the decaying fragments of plants. The food-canal runs as an open tube through the body-tube or body-cavity, which is divided by delicate partitions corresponding to the rings. There is a minute safety-valve dorsal pore for each ring.

The earthworm has no sense-organs, but it has numerous **sensory cells** in its skin, which respond to light, heat, vibrations, and chemicals. It is important to notice that although there are no eyes, the earthworm is sensitive to light; and so with other external influences. There is sensitiveness before there are sense-organs! The scattered sensory cells on the skin are responsive to different kinds of influences (or stimuli), just as sensory cells are when concentrated in special sense-organs, such as eyes, or ears, or nostrils. But the earthworm's senses remain at a relatively low level, for while the nocturnal and burrowing creatures are keenly aware of the difference between light and darkness, they cannot, of course, form an image. That requires an *eye*. And although they are exquisitely sensitive to vibrations in the soil, even to the light tread of the thrush's foot, it has not been proved that they can hear. That requires an *ear*.

The nervous system is what has been already described as the annulate type. There is red blood, with the same pigment (haemoglobin) that we ourselves possess; but it is carried by the fluid of the blood, not by red blood corpuscles as in backboned animals. There are four or five pairs of little contractile hearts. Breathing is discharged by the moist skin, oxygen diffusing into the blood, carbon dioxide diffusing out. There are about a hundred pairs of minute kidney-tubes, appearing to the naked eye as little transparent tubules, but showing great

complexity under the microscope. The reproductive organs are complicated, and the sexes are combined. Yet the eggs of one earthworm are fertilized by the sperm-cells of another. That is to say, there is cross-fertilization.

There can be little doubt that earthworms sprang from an aquatic stock, probably living in fresh water. A strong hint of this is given by the fact that a few earthworms, such as *Alma* and *Dero*, have minute gills on the side of the front end of their body. We can imagine

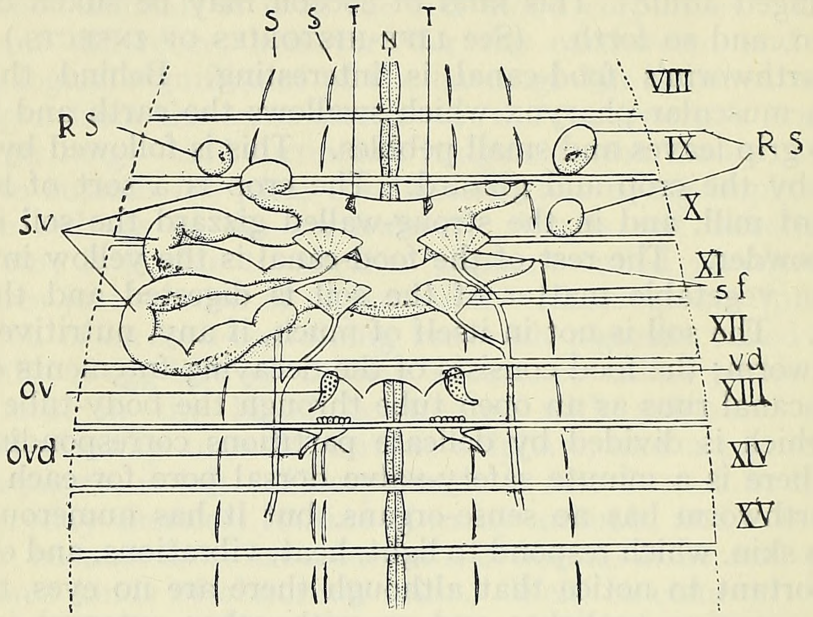


FIG. 62. REPRODUCTIVE ORGANS OF EARTHWORM.—After Hering

VIII–XV, segments; N, nerve-cord; T, anterior testes; S, sacs of setae; RS, seminal receptacles; *sf*, seminal funnels; *vd*, vas deferens; *ov*, ovary; *ovd*, oviduct; *sv*, seminal vesicles cut open.

that the drying up or overcrowding of water-pools led some pioneer Oligochaetes very long ago to the discovery of the possibilities of subterranean life. For a time they would have the underground world very much to themselves, and that was the golden age of earthworms. But, as ages passed, other animals made the same discovery—such as centipedes, carnivorous burrowing beetles, some bloodthirsty slugs (e.g. *Testacella*), and, long afterwards, the moles. Thus earthworms, which had enjoyed freedom from molestation for a long time, came to be much persecuted creatures; and we must think of their habits in the light of this persecution.

Thus earthworms have taken to nocturnal activity above ground, and this greatly reduces their risks. Those we sometimes see on the surface in broad daylight have been flooded out of their burrows by the rain, or have fallen victim to internal parasites, such as the larvae

of a fly. To imagine that the early bird catches an early worm is not good Natural History, for what the early bird catches is the belated worm that stayed out too long. It is interesting to flash a lantern on a stretch of lawn to get a glimpse of the multitude of earthworms that prowl about by night, and we may realize this in another way by noticing the number of worm-trails on the footpath after a showery night. During these nocturnal expeditions the earthworms are searching for pieces of plants and vegetable refuse lying on the surface, or seeking for others of their kind with which to pair.

There can be no doubt that the earthworm's exquisite sensitiveness is of life-saving value. The creature is so instantly aware of tremors in the soil that it can avoid the approach of the blackbird or the hedgehog or the mole. In some cases the hind end of the body is kept in the hole, and the worm can jerk itself back almost instantaneously. This is a good illustration of a **reflex action,** which we may take this opportunity of explaining, though it is simpler in the case of the earthworm than in backboned animals or in ourselves.

REFLEX ACTIONS.—In the skin of the earthworm there are numerous nerve-cells (or **neurons**) which receive messages or provocations (or **stimuli**) from the outside world. It may be light or warmth, a scent or a chemical, that provokes or stimulates these irritable cells. As they *receive* news from without, these *sensory* neurons are called **receptors,** and the result is that a rapid change travels from each stimulated cell down a delicate nerve-fibre to the earthworm's nerve-cord which runs along the middle line of the under-surface just beneath the skin. In the nerve-cord the end of each nerve-fibre divides into two, one tiny branch going headwards for a short distance, and the other going in the opposite direction. It is just the same when a nerve-fibre enters our own nerve-cord or spinal cord. Among animals, a common rate for the passage of a nerve-thrill is a hundred feet per second; in ourselves it is nearer four hundred feet per second.

Now the endings of a branch of the sensory nerve-fibre in the nerve-cord come into close contact with the branches of another kind of nerve-cell called **associative,** and this in turn is in connection with a third kind of nerve-cell called **motor.** The thrill or stimulus travels from sensory to associative and from associative to motor cells, though not in such a direct way as an electrical current passes from one piece of metal to another. From the motor nerve-cell it travels by a motor nerve-fibre to a muscle-cell in the earthworm's body-wall, which forthwith contracts. As a matter of fact, no message is ever so simple that it affects only one sensory, one associative, one motor, one effector cell; but theoretically the **reflex arc** is complete when there are these four links. In some of the earthworm's simplest answers-back the second link—of associative cells—is omitted.

One may make a useful mnemonic by representing a reflex action thus: *Sensory → Associative → Motor → Effector:* S A M E. One can never fail to follow the general idea of the chain of events, if one thinks of the sensory nerve-cells as scouts, gathering information; of the associative nerve-cells as general headquarters, where the news is sifted and combined; of the motor neurons as executive officers, like majors and captains; and of the muscle-cells as the soldiers or 'men' who get the thing done. It has taken a long time to give an elementary account of the earthworm's reflex actions, but it comes about in the animal with such rapidity that the jerk back in its hole does not take so long as we need to say 'Animal behaviour.'

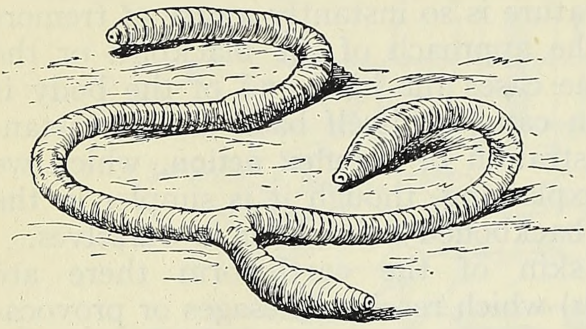


Fig. 63. Earthworm with Two Tails

Another quality of earthworms may sometimes be of advantage, that they have considerable power of repairing injuries. A clean cut with a spade may separate the head-end or the tail-end, and either can be regrown. It is probable that in natural conditions a clean cut of this sort may sometimes result, as when a bird snaps with the sharp edge of its bill.

So we see that in their nocturnal habits, in their sensitiveness to outside provocations, and in their power of **regeneration** (or replacement of lost parts) earthworms are able to hold their own in face of much persecution. It is also an advantage to be able to thrive on a diet so abundant as the vegetable matter in the soil.

AGRICULTURAL IMPORTANCE OF EARTHWORMS.—(1) The burrows of earthworms are often over a foot deep; they are made by eating the soil and by pressing the body with its glandular skin against the sides of the shaft; they are sometimes partially lined with leaves; there is often an enlargement at the lower end where the worm can turn; in many cases the opening on the surface is guarded by a little heap of pebbles, which may lessen the risks of flooding and deter intruding centipedes. As Gilbert White said, the burrows of earthworms make way for plant roots and raindrops. They also let air into the soil and thus help in weathering. The first work of earthworms is *burrowing*.

(2) In the muscular hard-walled gizzard of the earthworm the particles of soil are broken into finer dust, which is voided on the surface in the form of the familiar 'worm-castings.' The earthworm's gizzard is thus one of the most important mills in the world, for the grinding of the soil means that there is a larger surface on which the

soil-water can act and dissolve the mineral matter. Thus the second great work of earthworms is *bruising*, and this means soil-making and enriching the soil-water.

(3) When the earthworms come to the surface tail foremost, they void the earth that has passed through their food-canal and has had much of the decaying vegetable matter digested out. This means covering the surface with castings, turning the soil round, bringing up what was down and gradually bringing down what was up. It is a sort of ploughing. The castings are exposed to the rain and often washed away in runlets, to make alluvial soil somewhere else. They are also weathered by rain and frost; and one must not forget that bacteria in the soil are brought to the surface in castings. Some may be killed by the sunlight, and this may be useful if they are hostile bacteria; but others may be blown about by the wind, and if they are dangerous bacteria, like those causing lockjaw (or *tetanus*), this will increase possibilities of disaster. For a man working in the ground might get some of the microbe-containing soil into a cut on his hand. This third work of earthworms may be called *ploughing*, and Darwin showed that in cultivated ground, with fifty-three thousand earthworms on an average in an acre, they bring ten tons of soil to the surface of an acre in a year, and that they cover the surface with earth at the rate of three inches in fifteen years. He tells of an unploughed field that he watched for many a year. To begin with it was covered thick with stones, but thirty years afterwards they were so thoroughly buried by the worm-castings that a horse could gallop across without knocking its shoes against one of them.

(4) The fourth great work of earthworms is *burying leaves*, which are gripped by the mouth and drawn down into the burrow. We once observed that ninety-one leaflets were drawn into one hole in a short time. These were leaflets of the rowan tree or mountain ash, seven of which go to make a leaf, and the thirteen tough midribs were lying round the mouth of the hole, curiously like the spokes of a wheel. Now if ninety-one leaflets were drawn down in a short time into one burrow, what millions must be buried in a single parish every year! Some of the leaflets are eaten, but others rot away, and this contributes greatly to the formation of vegetable mould. It may be noted here that earthworms often drag down more or less unprofitable things, such as feathers and little pieces of twine. They are simply obeying their instinct to lay hold of anything that is soft and flexible as leaves are. Darwin noticed that earthworms often deal effectively with rather difficult leaves, such as the twin needles of the pine, which they grip by the base.

EARTHWORMS AND FEATHERS.—We have noted that earthworms are very busy in the soft soil—making deep burrows, bruising the

earth to powder in their gizzards, burying the surface with their castings, and burying the leaves that make the tunnels more comfortable and rot away into edible mould. They are among the most useful animals in the world, having made and continuing to make the fertile soil. But sometimes they exert themselves not very profitably. Thus they take feathers down into their burrows, and sometimes the feather dragged in is so big that it sticks in the shaft, leaving the upper half sticking out vertically. When a sparrow-hawk was daring enough to kill a chaffinch on our lawn and to devour it at a short distance from the windows, we noticed the interesting fact that by next morning the earthworms had taken at least half a dozen of the little plucked-off feathers into their burrows. These would make the burrows more comfortable, but they could not be of use for food. This illustrates what is sometimes called **blind instinct.** It is instinctive in earthworms, which are literally blind, to drag in leaves, and they cannot be expected to draw the line very accurately between leaf and leaf-like. It is difficult to believe that they get much good out of hard and sharp leaves like those of the Scots fir, though they treat them effectively enough, gripping at the base, where the two needles unite. If we were earthworms we should similarly deal with sharp forks, dragging them into our cave by the base. This we should call ' reason ' if we acted from the first on general principles, or ' intelligence ' if we were dull enough to require to learn how to do the trick. The question is what word we should use when earthworms act so effectively. Is it a ready-made, inborn, hereditary instinct, or do the earthworms learn how to deal with difficult leaves? Even Darwin did not settle this point.

To sum up: Earthworms are of immense agricultural importance because of their burrowing, their bruising, and their burying. They have made a great part of the fertile soil of the earth. As Darwin said: ' It may be doubted if there are many other animals which have played such an important part in the history of the world as these lowly organized creatures.'

There are a great many different kinds of earthworms, with considerable variety of habitat. Thus *Dendrobaena* climbs trees; *Alma nilotica*, with branched gills, lives in the mud of the Nile; a few come near or on to the seashore, not showing the ordinary earthworm's antipathy to salt; the brandling (*Allolobophora*), which anglers search for, is fond of dung-heaps. The luminescence which some good observers have recorded in the brandling is possibly due to luminous bacteria on the moist skin. There is a Java monster, *Perichaeta musica*, several feet in length, which makes a sharp sound as it creeps about at night, probably by the bristles clicking against stones! The giant Tasmanian earthworm, *Megascolides gippslandicus*, is said

to attain a length of six feet, and to retire into its burrow with a gurgling noise.

FRESHWATER WORMS.—When we examine the mud of streams we often find slender ringed worms which are related to the terrestrial earthworms. Many of them have long slender bristles. They are sometimes reddish because the blood shines through, as in the common *Tubifex rivulorum*; or they may be brightly coloured with oil-globules as in the not uncommon *Aeolosoma*. In many cases, as in *Nais*, there is asexual multiplication, one worm dividing into two. *Branchiobdella* has jaws and suckers and hangs on to the gills of the freshwater crayfish. In *Dero* and *Branchiura* there are gills, showing how exceptions occur to most rules, for almost all the bristle-worms with relatively few bristles (*Oligochaeta*) illustrate **cutaneous respiration.** That is to say, almost all earthworms and freshwater worms breathe through the blood-vessels spread out in their skin. Oxygen diffuses in and carbon dioxide diffuses out—the simplest and most primitive mode of 'breathing.' The capturing of oxygen is made easier when there is haemoglobin (red pigment) in the blood, and that is the case in the great majority of these worms.

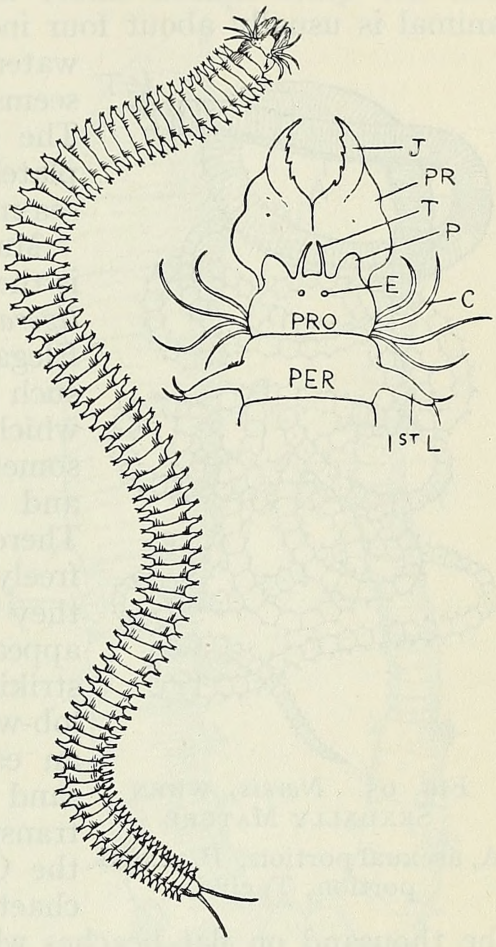


FIG. 64. *Left:* NEREIS. *Right:* HEAD OF POLYCHAETE WORM

PR, protruded pharynx, bearing jaws (J); PRO, prostomium, bearing tentacles (T), palps (P), eyes (E), and four paired cirri (C); PER, peristomium, bearing first pair of legs (1st L) or parapodia. (In *Nereis* the peristomium does not bear parapodia.)

RINGED SEA-WORMS OR POLYCHAETES.—Among the jetsam on the seashore one sometimes finds the sea-mouse (*Aphrodite aculeata*), one of the most striking bristle-footed marine worms. When the sand that adheres to it is washed away, the body shines like a piece of rainbow. In other words, many of the bristles show **iridescent colours,** which are due to the fine markings on their surface. On each side of the under-surface there is a row of stout appendages or limbs, which are used in creeping about in the mud or sand. Such worm-limbs

are technically called *parapodia* (p. 146), and they often carry thin flat leaflets which may help in breathing, and also sensitive outgrowths called *cirri*. In the sea-mouse there are fifteen pairs of these cirri, turned into flattened plates (*elytra*) which lie along the dorsal surface, but are quite hidden under a matted felt-work of bristles. The animal is usually about four inches long; it lives in deepish inshore waters among the coralline seaweeds; it seems to be a favourite morsel for codfish. The scale-backs (*Polynoë*), with exposed platelets or elytra, are like attempts at sea-mice.

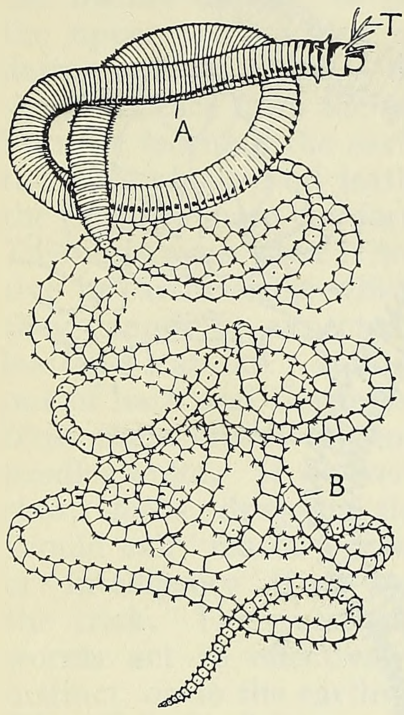


FIG. 65. *Nereis*, WHEN SEXUALLY MATURE

A, asexual portion; B, sexual portion; T, cirri.

Much more elegant than the sea-mouse is the green paddle-worm (*Phyllodoce lamelligera*), which is often about a foot long. Elegant also are various kinds of *Nereis*, such as the long and strong *Nereis virens*, which bait-seekers call the 'creeper.' It sometimes approaches two feet in length, and wriggles formidably in one's grasp. There are hundreds of different kinds of freely moving ringed worms in the sea, and they show an extraordinary variety of appearance and habit. Thus there is a striking contrast between the fisherman's lob-worm (*Arenicola piscatorum*), that lives an earthworm-like life, burrowing in the sand of flat beaches, and the delicate, transparent, free-swimming *Tomopteris* of the Open Sea; yet both are true Polychaetes. The worm-castings often seen by the thousand on flat beaches when the tide is out are made by the lob-worm or lug-worm, which passes the sand through its food-canal for the sake of the organic particles and small living creatures to be found there. In most cases the tubes of the lob-worm are U-shaped, and the tail may appear at one opening to void the sand when the tide is out, while the head may appear at the other end when the tide comes in. It has been calculated that in some places where lob-worms are abundant, the castings may amount to an annual total of 1,900 tons per acre. The old-fashioned line-fishermen, who spread long buoy-supported lines with dangling hooks in the sea, often use the lob-worm for bait. It is in some ways a pity that this wholesome calling is rapidly decreasing in face of the formidable competition with trawlers. In the trawling method, the men make use of a strong net supported and kept taut in various ways, which is dragged along

the sea-floor, and yields a much more abundant catch than can be got from the hook. But the line-caught fish are often in better condition than the trawled fish, and therefore more profitable to the eater. Quality is sometimes better than quantity.

It is instructive to put a living lob-worm into a pool of water on the sand to see its movements and also its thirteen pairs of red **gills.** Each gill, in this particular case, is a tuft of thread-like branches, on which the blood is spread out; and a gill in general may be defined as a structure suited for spreading out the blood-vessels or blood-channels so that a large surface is exposed to the water. The gills of a lob-worm, a lobster, an oyster, and a fish are very different from one another, but they have this in common, that the blood is spread out over a large surface separated from the water by a delicate living membrane. Oxygen that was dissolved in the water passes into the blood, and carbon dioxide from the blood passes into the water. This is gill-respiration or branchial respiration (*branchia*, a gill), and it is an improvement on skin-respiration or cutaneous respiration, because of the large surface that is secured by the branched or feathery or expanded shape of the gill, and also because the covering of the gill can afford to be more delicate than the general surface of the skin. Thus the two gases pass more readily in and out. One of the great expedients, if we may use this word, in the life of animals is increase of surface, and a simple illustration of this is to be found in gills. They may be compared sometimes, as in lobster and fish, to a country with a large coast-line. It will be understood that 'gill' is a physiological word, for a great many quite different structures, even in these marine worms, may be used as 'gills.'

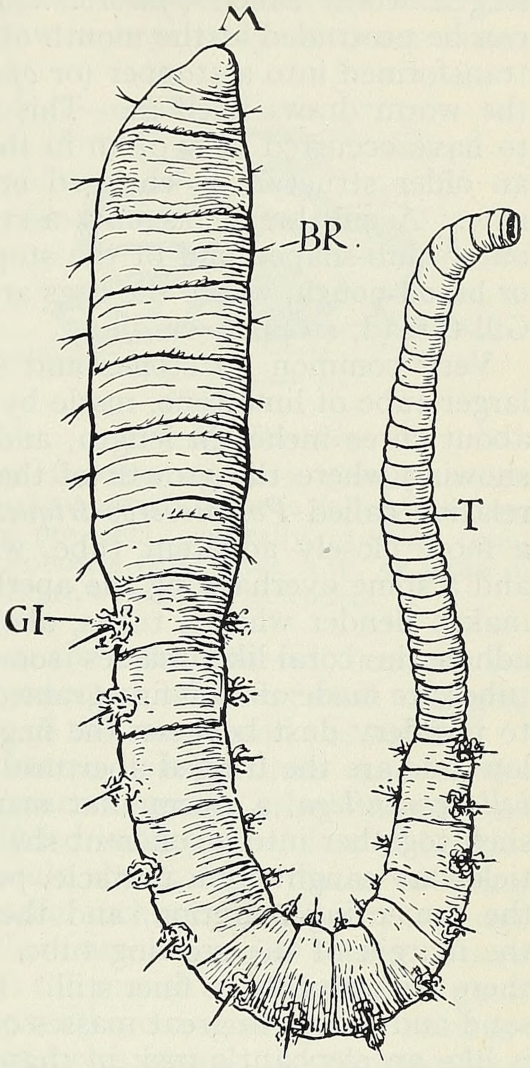


FIG. 66. LOB-WORM OR LUG-WORM (*Arenicola marina*)

BR, bristles or setae; GI, gills; M, mouth; T, thinner rail region.

TUBE-INHABITING WORMS.—A great many of the marine worms are sedentary and live in tubes. One can hardly lift half a dozen pieces of the bladder-wrack seaweed (*Fucus vesiculosus*) without finding on one of them a little flat spiral of limestone, the tube of a ringed worm called *Spirorbis*. It has branched gill-threads which can be protruded at the mouth of the tube, and one of these has been transformed into a stopper (or *operculum*) which shuts the tube when the worm draws itself in. This is a simple instance of what seems to have occurred very often in the evolution of living creatures, that an older structure is changed or transformed into something quite new. A gill-thread becomes a stopper. But that is not all, for the outer club-shaped end of the stopper is turned into a kind of cradle or **brood-pouch**, where the eggs are sheltered and development begins. Gill-thread, stopper, cradle!

Very common on stones and shells are various forms of a much larger tube of limestone, made by a worm called *Serpula*. It is often about three inches in length, and pinkish in colour, with cross-rings showing where the growth of the tube had stopped for a while. A relative called *Pomatoceros triqueter*, a very handsome worm, makes a more closely adherent tube, with a keel along its dorsal surface, and a spine overhanging the aperture. The filigree-worm (*Filograna*) makes slender whitish tubes, about the thickness of a needle, which adhere in coral-like masses sometimes as big as a football. The tubes are made of such fine-grained material that they can be crumbled to powdery dust between the fingers. Protruding out of the sand at low tide are the fringed apertures of the flexible sandy tubes of *Terebella conchilega*, a worm that manages to glue particles of sand and shell together into a coherent shelter. It makes ropes of sand. Particles are caught by a tentacle, put into the mouth for a moment for the cementing secretion, and then fitted by another tentacle on to the margin of the growing tube. The building is very effective and there are worm-tubes finer still. In *Sabellaria* they are made of coarse sand and cohere in great masses on the shore. In *Pectinaria* the tube is like an elephant's tusk in shape, open at each end, and composed of small sand-grains uniform in size, firmly cemented together. In the deep-water luminescent *Chaetopterus* the tube is loose-fitting and parchment-like; in *Hyalinoecia* it is translucent. There is a very interesting variety of worm-tubes.

PALOLO-WORMS.—Many of the ringed worms of the sea live in the crevices of the coral reefs, and two or three different kinds give rise to what is called a swarm of palolo. The one that lives on the Samoan coast is a narrow delicate creature, green in colour, called *Leodice viridis*. In the fall of the year the body becomes full of egg-cells or sperm-cells, and in October or November, at the last quarter of the

moon, for a short time before sunrise, the palolo-worms become very restless. They back out of the narrow passages amongst the coral; they break off the body at a short distance behind the head; the headless bodies writhe in the water and burst; the eggs are fertilized by the sperms; a new generation begins. The heads creep back into the coral crevices and gradually grow a new body of many rings. The natives fill baskets with those headless bodies that get washed ashore, and it is said that the land-crabs come down to the shore to join in the feast. There are some related sea-worms that burst and die when they liberate their egg-cells and sperm-cells, but while the palolo-worm bursts, it does not wholly die. For the head lives on, either remaining on the reef or creeping back. A noteworthy feature in the palolo swarm is the regularity of its occurrence and its association with the state of the moon. There is a periodic internal change in the worm when it becomes reproductive, but this is somehow connected with external changes, especially the time of year, the phase of the moon, and the sunrise.

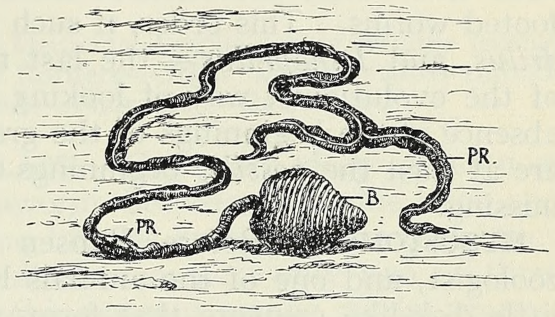


FIG. 67. *Bonellia*
The drawing shows a female, which has a body (B) about 2 in. long, bearing a pre-oral, ventrally-grooved, bifid proboscis (PR) often 6 in. or more in length when fully extended.

ECHIURIDS.—Besides the Oligochaetes (earthworms and fresh-water worms) and the Polychaetes (marine worms), there is another order (*Echiurids*) which must be included in the same class of bristle-footed worms. The body of the adult shows only traces of being ringed, there are no limbs or parapodia such as are present in most Polychaetes, there are no gills, and there are only a few setae. There is a long solid proboscis which carries the mouth at its base. A good example of this small order is *Echiurus*; all are marine. Very remarkable is *Bonellia viridis*, which lives in holes among the rocks on the warmer coasts of Europe. The female, of a beautiful green colour, has a body about the size of a prune, but the bifid proboscis which probes for food is often six inches in length or more. The male is a degenerate pygmy, without mouth or anus, an instance of **arrested development.** It is only about one-sixteenth of an inch in length. The free-swimming larva settles down on the proboscis of a female and seems to be arrested by absorbing the secretion from the skin. Thence it passes by means of its cilia to the female's mouth, and eventually it makes its way to a kidney-tube or nephridium through which the eggs pass out, fertilized *en route*. The free-swimming larvae that

settle in the mud develop into the large females. This is one of the most extraordinary instances of **sex-dimorphism** in the animal kingdom.

PRIMITIVE WORMS.—There are a few small, simple marine worms which may be primitive and ancestral, and have therefore received the name of *Archi-annelids*. But it may be that their simplicity is due to arrested development, brought about by the conditions of their life. They are without the setae characteristic of the bristle-footed worms. This order, if such it is, includes *Polygordius*, *Protodrilus*, and *Dinophilus* — the last the simplest of all. Some critics of the evolutionist way of looking at things fasten on the supposed absence of the beginnings of the great classes, but the Archi-annelids are at least the *possible* beginnings of Annelids. Links are not always missing.

MYZOSTOMUM.—Before Nansen became an explorer he was a zoologist, and one of the animals he worked at was *Myzostomum*, a little disk-like creature that forms galls on feather-stars or Crinoids. There are several different kinds, some of them hermaphrodites with pygmy males, and they are possibly degraded by parasitism.

CHAPTER IX

LEECHES AND OTHER CLASSES

Leeches. A well-defined class—The Medicinal Leech—Other notable leeches—Arrow-worms—Wheel Animalcules or Rotifers—Other 'worms'—Moss-animals or Bryozoa—Lamp-shells or Brachiopods—Phoronids—Retrospect.

LEECHES. A WELL-DEFINED CLASS.—There are deep differences between a land-leech and an earthworm, between a marine leech and a lob-worm. Thus leeches have no bristles except in one case; they have a suctorial mouth and an adhesive sucker; only two or three have gills, which are common breathing organs among marine worms. The rings that mark the surface of the body are more numerous than the true segments of the body, which are marked by the nerve-centres and other internal structures. The body-cavity is usually much reduced, being filled up with connective tissue. Like earthworms, leeches are hermaphrodite, i.e. there are male and female organs in the same individual. The development is direct, i.e. what hatches out of the egg is a miniature of the adult. Most leeches live in fresh water and on land; a few are marine.

Leeches are muscular animals, but they cannot be called very lively. Some swim gently by undulating the body; the usual mode of locomotion is by alternately fixing and loosening the suctorial mouth and the posterior adhesive sucker. Some of them have toothed or untoothed jaws by means of which they make a neat incision in a victim's skin, and then suck blood. Others have no jaws but protrude a muscular pharynx on small animals. Even those that fasten themselves to frogs and fishes should not be called parasites; they are predatory animals that work energetically for their living. Gills are present on *Branchellion* from the torpedo and on *Ozobranchus* from a Chinese river-turtle, but all other leeches breathe through the skin. Oxygen diffuses into the blood, and carbon dioxide diffuses out—the simplest mode of respiration, **cutaneous respiration.** Many leeches have red blood, but the pigment is in the fluid, not in red blood corpuscles as in backboned animals.

THE MEDICINAL LEECH.—This familiar animal, technically called *Hirudo medicinalis*, was once so much used in the practice of medicine that its name became equivalent to physician. In old books we read that they sent for the leech, when we should say they sent for the doctor. It is not much used nowadays and 'leech-farms' are no

longer important. Leeches are at home in ponds and sluggish streams, where they occasionally suck blood from frogs and fishes. As opportunities are few and far between, a leech makes the most of a meal. It gorges itself with blood, filling the eleven pairs of pockets that make up its crop. Blood is very nutritious and the leech's digestion is very slow, so a big meal may last for many months. There are minute glands in the muscular pharynx, which secrete a fluid that keeps the insucked blood from clotting. And here it may be mentioned that in association with the nervous system of the leech there are **chromaffine** cells precisely similar to those that secrete the hormone adrenalin in backboned animals (see HORMONES). Similar cells have been found in two or three other cases, as in the marine worm called the sea-mouse, but, apart from these indications, hormones are little known in backboneless animals.

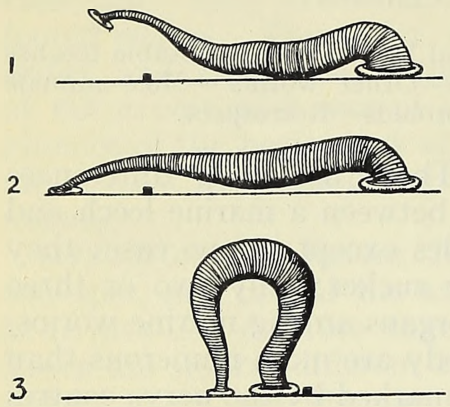


FIG. 68. DIAGRAM SHOWING MOVEMENTS OF A LEECH (*Hirudo*)

If the leech is provoked, it will swim about actively and gracefully; and its ordinary looping movements are well worth watching. It fastens its mouth, loosens its posterior sucker, and draws its body forwards by contracting the longitudinal muscles. When the posterior sucker is just touching the attached mouth, the body being arched up like a croquet hoop, the leech loosens its mouth and forces its body forwards by contracting the circular muscles from behind forwards. The narrowed anterior body, feeling its way, finds a new place of attachment for the mouth, and then the whole story begins again.

After a heavy meal the leech often casts its cuticle, contracting its body spasmodically or rubbing against water-weeds. The process may be watched in an aquarium; it means a sloughing of the non-living outermost pellicle, external to the living skin. If we examine a medicinal leech attentively, we may verify the following points. The body is two to six inches in length, cylindrical or strap-like according to its state of contraction. The dorsal surface is beautifully marked with longitudinal pigmented bands; the ventral surface is irregularly mottled. The suctorial mouth is ventral, but the posterior or anal opening of the food-canal is dorsal, just above the disk-like posterior sucker. The skin includes numerous gland-cells, the secretion of which makes the animal very slimy. The mucus is also used to make a cocoon for the eggs. There are a hundred and two skin-rings and twenty-six true segments, but the hind sucker is believed to correspond to seven more segments, making a total of

thirty-three. Except towards the two ends, five rings go to a segment. The head-end bears five pairs of 'eye-spots,' and there are sensitive patches at regular segmental intervals along the body. The male opening is between rings 30 and 31; the female opening is five rings further back. Numerous eggs enclosed in cocoons are deposited in the damp earth near the edge of the pool, and from each egg there comes a miniature leech.

OTHER NOTABLE LEECHES.—One family of leeches (called *Rhynchobdellids*: *rhynchos*, proboscis; *bdella*, leech) is marked by the absence of jaws or tooth-plates, by the protrusible pharynx (forming the proboscis), by the colourless blood, and so on. Here are included the little brook-leeches (*Glossiphonia* or *Clepsine*) very often seen when we turn up a flat stone in a sluggish part of the river. It is interesting to turn some of these leeches upside down, for they illustrate a simple form of **parental care.** The parent carries first its eggs and afterwards its young ones on the under-surface of its body. The posterior sucker of the miniature leech is fastened to the ventral surface of its parent's body, and this must save it from being washed away when the current is strong. In cases like this there is, of course, no cocoon. Belonging to the same family is the large skate-sucker (*Pontobdella muricata*), which may be six inches long. It has a greenish colour and a very rough skin. Both anterior and posterior suckers are very sharply defined; the narrower region of the body is in front. This leech is sometimes found attached to skates and sharks. It is so sensitive to skate's flesh that if a piece be thrown into an aquarium where *Pontobdella* is lurking, the leech, if it cares, can catch it before it has sunk to the bottom. In this form also there is striking parental care, for it deposits its velvety cocoons, about the size of currants, in empty mollusc shells and

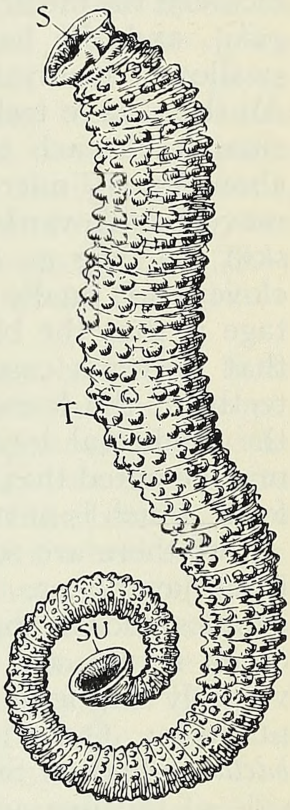


FIG. 69. THE SKATE-SUCKER (*Pontobdella muricata*), A MARINE LEECH
S, anterior sucker; SU, posterior sucker; T, tuberosity on leathery skin.

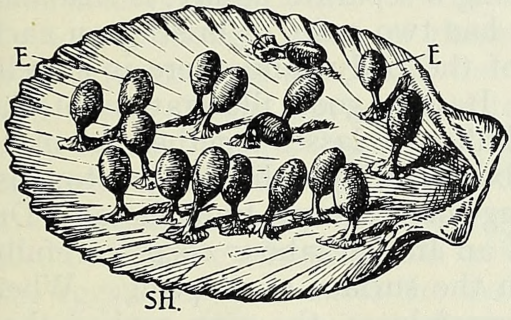


FIG. 70. VELVETY EGGS (E) OF THE SKATE-SUCKER, LAID IN AN EMPTY SCALLOP SHELL (SH)

mounts guard over them for more than a hundred days. Belonging to the same family is the large *Macrobdella* of North and South America, which may be seven and a half inches in length, and more when it stretches itself out in locomotion. It is a blind giant.

The second family, known as *Gnathobdellids* (*gnathos*, jaw; *bdella*, leech), is marked by the possession of three jaw-plates, by the absence of a protrusible proboscis, and by the red blood. The eggs are smaller and with less yolk than those of the proboscis leeches. Here are included the medicinal leech, the horse-leech (*Haemopis* or *Aulastomum gulo*), and the hair-like *Limnatis* of the Nile, which is sometimes swallowed in drinking-water and fastens to the back of the mouth. All these have teeth on the three jaws or tooth-plates. In the medicinal leech each tooth-plate is like a semicircular saw, for there are about ninety microscopic teeth along the edge. When the saws are moved downwards and inwards, three minute cuts are made in the skin; as they go on working, the wound becomes somewhat like a clover leaf; finally by coalescence it becomes triangular. The advantage is that the blood of the victim flows more freely; the secretion that prevents coagulation or clotting may also help the flow. The teeth on the horse-leech's jaw-plates are not so regular as those of the medicinal leech, and are thus unsuitable for blood-letting. It may be noted that a horse-leech can contract into an oval olive-shaped form, which is never assumed by *Hirudo*.

But there are some jawed leeches which are without teeth on the three jaw-plates. Among these are included the land-leeches of the Tropics, such as species of *Haemadipsa*. They lie in wait on the ground or on shrubs and can move quickly after a possible victim. Individually negligible, they may be very troublesome when in large numbers. Quite by itself, and forming a separate family, is *Acanthobdella*, found on Siberian fishes. It has two pairs of bristles on each side of the five anterior segments of the body; and there is a well-developed body-cavity or coelom. It is a good illustration of the way in which a divergent type may link two classes together, for in its bristles and its body-cavity Acanthobdella links leeches to Chaetopods.

GIDEON'S TEST. — When travelling in western Baluchistan, Dr. Nelson Annandale saw a member of an Indian labour corps carefully skimming water with his hand from the surface of a spring. When he was asked for a reason for his carefulness, the man replied that it was to avoid swallowing a leech. Further inquiry showed the presence of a leech called *Limnatis nilotica* on the borders, and even within the boundaries, of the Indian Empire. Many were observed at Robat close to the point at which the Afghan, Baluch, and Persian frontiers meet, and a specimen was got within the district of Seistan, fastened to the tongue of a horse. Now this leech occurs in Palestine,

and Gideon's test (Judges vii) may have been intended to discriminate between the careless and reckless who drank directly from the water, and the careful and more controlled who lifted the water in their hand to their mouth, and were therefore safe from the risk of swallowing a leech. The agricultural moral is that horses should not be allowed to drink from stagnant pools. The human moral is: *Hasten slowly.*

ARROW-WORMS.—Perhaps related to the ringed worms or Annelids are a few Open-Sea 'worms' (*Sagitta* and *Spadella*), which look like living glass-arrows. They vary from an inch to three inches in length, and are extremely abundant *pelagic animals*. They are quite transparent, lightly built, quickly moving. There are grappling-hooks and small spines beside the mouth, hence the technical name *Chaetognatha*, which means 'bristle-jawed' (*chaeta*, bristle; *gnathos*, jaw). The food consists of diatoms, infusorians, small crustaceans, and larval fishes. They may do considerable harm to fisheries, but they also form part of the food-supply of Open-Sea animals. They are hermaphrodite, and the eggs which are liberated in the surface-waters develop very rapidly.

WHEEL ANIMALCULES OR ROTIFERS.—These are beautiful little animals, favourites of those who enjoy to peer into the microscopic world. They are abundant in fresh water, in damp moss, and in the sea. Some live in fixed tubes, others are free. They owe their names to the movements of the cilia at the anterior end of the body in front of the mouth, for there is an illusory suggestion of a wheel or something rotating. These cilia make a whirlpool through which still smaller organisms or invisible particles are wafted into the mouth. Some of the Rotifers are so small that they can go through the eye of a sewing-needle, yet one of these has rather more than nine hundred cells in its minute body. So they are very different from the unicellular Protozoa, though many of these are bigger than any Rotifer. It is not a question of size; it is the deep distinction between unicellular and multicellular, between Protozoa and Metazoa. There are some very interesting peculiarities in Rotifers. Thus the males are usually degenerate dwarfs and often quite useless. Many if not most Rotifers are **parthenogenetic,** i.e. the eggs develop without being fertilized. Even if a male effects sexual union, the sperms do not seem to affect the eggs. In some cases the males have never been found. Rotifers are very tenacious of life and can survive prolonged drought in a state of **suspended animation.** After a time the bodies die, but the contained eggs may live longer, and may develop if water is restored. It is possible that Rotifers were evolved from ancestors something like the larvae (trochospheres) of marine Annelids, and that is why we have placed them here.

OTHER 'WORMS.'—It is unfortunately necessary to recognize

many different classes of more or less worm-like animals. It is unfortunate because it makes the classification very complicated; yet it is necessary because we cannot group together animals that are deeply dissimilar. Thus there are the Sipunculids, e.g. *Sipunculus*, and the Priapulids, e.g. *Priapulus*. These are different from all other worms, and from one another, but they agree in being marine, in living in sand or mud which they swallow, in having a protrusible proboscis with the mouth at its tip, and in having unsegmented bodies with a spacious body-cavity.

MOSS-ANIMALS OR BRYOZOA.—These common animals, also called *Polyzoa* (since the group includes so many varied forms), are for the most part colonies, and bear a superficial resemblance to Hydroids. But they are much more complicated, and are near the level of worms.

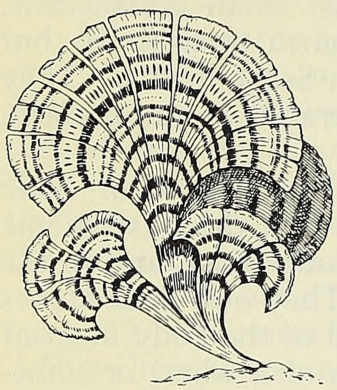


Fig. 71. The Sea-mat (*Flustra*)

A very familiar type is the sea-mat (*Flustra*), which is often thrown up on the shore. It is very like a piece of brown seaweed, but a lens shows it to consist of a large number of little chambers or 'cells,' each of which is the residence of a small animal like a worm bent on itself. It was about this sea-mat that Darwin wrote his first scientific paper. It is a general feature of the Bryozoa that the mouth is surrounded by a crescent or a circle of tentacles that waft food into the mouth; and the class is divided into two very distinct sub-classes according as the anus is outside or inside of the tentacular enclosure. The *Ectoprocta*, with the anus outside, include freshwater and marine forms. The freshwater forms are well represented by *Cristatella* and *Lophopus*. The marine forms include the sea-mat, like a piece of seaweed; *Membranipora*, spreading like lace on tangle and shell; *Cellepora*, like a miniature coral; and *Alcyonidium*, which is in some species gelatinous. Some of the marine colonies are very interesting in showing **division of labour** or **polymorphism**, as in some hydroid zoöphytes. Thus an individual may become transformed into a snapping structure (*avicularium*) like a microscopic bird's head, and others take the form of long mobile whips (*vibracula*). The use of these strangely transformed individuals remains very obscure, but it may be that they drive off undesirable intruders. Another very interesting feature of many Bryozoa, such as the sea-mat, is their quaint way of becoming old and then becoming young again—a kind of **rejuvenescence.** There is a breaking-down of tentacles, food-canal, and nervous system, and the débris becomes compacted into a 'brown body.' From the wall of the 'cell' a bud grows inwards which develops into a new individual. The stomach

of the new individual surrounds the ' brown body,' most of which is absorbed and breaks up. The useless material is got rid of from the food-canal of the new individual. Thus senescence or growing old is conquered by rejuvenescence or becoming young again.

LAMP-SHELLS OR BRACHIOPODS. — These are very ancient animals, dating from the very earliest fossil-bearing rocks, and reaching their maximum in the Ordovician and Silurian periods. Nowadays they are dwindling, though there are still many. The name **lamp-shell** refers to the resemblance that many of them

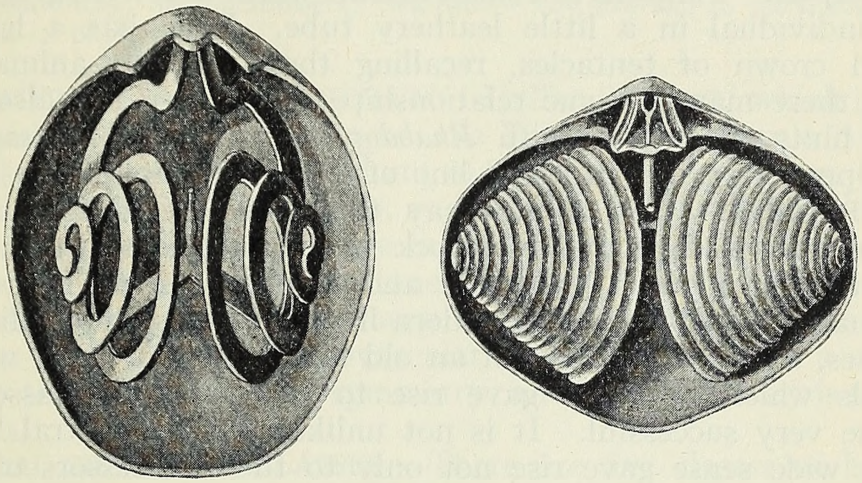


FIG. 72. INTERIOR OF BRACHIOPOD SHELLS

have to an ancient Greek lamp. The complicated animal is enclosed dorsally and ventrally in two folds of skin, which secrete the two valves of the shell, usually calcareous, but sometimes only organic. One cannot help thinking of the two shell-valves of a bivalve mollusc like a cockle, but there is no real resemblance. The valves of the lamp-shell are dorsal and ventral, while those of a bivalve mollusc are right and left, like the flaps of a man's jacket. As to the animals, they are as different as different can be. When we are fortunate enough to get a well-preserved lamp-shell that we can open, we find that a considerable part of the internal space is occupied by two long ' arms,' coiled in a spiral and often supported by a calcareous skeleton. Deep within the bases of the ' arms ' is the mouth, and there can be little doubt that the ' arms ' correspond to the horseshoe or wreath of tentacles in Bryozoa. They are covered with invisible cilia and they waft food into the mouth, besides keeping up water-currents which will help in aëration or respiration. As examples of Brachiopods we may mention *Lingula*, which has persisted without appreciable change from Lower Cambrian times till to-day, a conservative, well-balanced type, lasting for several hundred millions of years. The

shell shows alternating layers of chitin and limestone. The tongue-like shell is at the end of a long stalk fixed in the sand. *Crania*, also very ancient, has an almost circular calcareous shell, perforated by tubules. In most lamp-shells there is a more or less elaborate 'hinge' between the valves, as in *Rhynchonella*, surviving since the Ordovician, and *Terebratula*, surviving since the Devonian. All living Brachiopods live in the sea, from shallow water to great depths.

PHORONIDS.—Yet another of these puzzling classes of 'worms' must be noted, the *Phoronidea*, including the genera *Phoronis* and *Phoronopsis*. Phoronis is a small marine worm that lives gregariously, each individual in a little leathery tube. Each has a horseshoe-shaped crown of tentacles, recalling those in moss-animals, with which there may be some relationship. But there are also, in the larva, hints of affinities with *Rhabdopleura* and *Cephalodiscus* which are approaching the ancestral line of backboned animals.

RETROSPECT.—Just as we may think of ancient Reptiles as a very diverse and progressive stock of Backboned Animals, making tentatives in various directions and reaching on to Birds and to Mammals as well as to the modern lizards, snakes, crocodilians, and tortoises, so we may think of an old and varied stock of worm-like animals which probably gave rise to several other classes which became very successful. It is not unlikely that ancestral 'worms' in the wide sense gave rise not only to their successors of to-day, but to Echinoderms, Molluscs, Bryozoa, Brachiopods, Arthropods, and even Vertebrates. From a stretch of moorland we may find streams that eventually flow into widely separated seas, and the ancestral 'worms' may be compared to such a moorland, from which many different streams of life have flowed to distant issues. Let us recall that worms began the habit of moving head foremost, which was the beginning of our knowing our right hand from our left.

CHAPTER X

ECHINODERMS OR PRICKLY-SKINNED ANIMALS

Distinctiveness of this phylum—General survey of classes: Starfishes; Brittle-stars; Sea-urchins; Sea-cucumbers; Sea-lilies—The Starfish in particular—The Sea-urchin in particular.

DISTINCTIVENESS OF THIS PHYLUM.—Unlike ' worms,' which include such a perplexing variety of types, the Echinoderms form a compact and well-defined group (or phylum) of classes—the starfishes, brittle-stars, sea-urchins, sea-cucumbers, and sea-lilies, besides several classes altogether extinct. They all live in the sea; most of them are rather sluggish and with much limestone in their tissues; their nervous system shows very little in the way of centres or ganglia; they have a peculiar hydraulic or ' water-vascular ' system; they show a marked tendency to be radial in their symmetry; and the life-history is usually circuitous.

GENERAL SURVEY OF CLASSES.—There are five classes of Echinoderms with living representatives:

(*a*) **Starfishes** or **Asteroids,** mostly with five arms and a conventional star shape, with a mouth in the middle of the under-surface; the anus or vent, if present, is dorsal. A good many organs, such as the reproductive organs, are continued into the arms. Starfishes move by means of numerous suctorial and contractile tube-feet situated in a ventral groove along each arm. In most cases there are minute, peculiarly shaped, free-swimming larvae, which undergo a great change or metamorphosis in giving rise to the permanent shape. Examples: the common starfish (*Asterias*); the sun star (*Solaster*); the pincushion star (*Porania*); the webbed star (*Palmipes*).

(*b*) **Brittle-stars, Sand-stars,** or **Ophiuroids.** From a flat pentagonal disk five arms project abruptly. Most of the organs are confined to the central disk, but the arms are full of muscle, and are used in a wriggling kind of locomotion. In most cases the tube-feet are too small to be used in locomotion, but they may help in breathing. There is no open ambulacral or tube-foot groove. The mouth is in the middle of the under-surface; the food-canal is blind. The free-swimming larva is called a *Pluteus*, and is like a painter's easel with many legs. Examples: *Ophiura*; *Ophiothrix*; *Amphiura*; *Astronyx*

with very long arms; *Gorgonocephalus*, the gorgon-headed brittle-star, with arms repeatedly bifurcated.

(*c*) **Sea-urchins** or **Echinoids.** Mostly of globular shape, but sometimes heart-like, or depressed like a thin cake ('sand-dollars'). In almost every case the shell or test is quite rigid. The surface is usually covered with sharp spines, moving on ball-and-socket joints, and there are many small snapping blades (*pedicellariae*) which throw off entangled objects, or poison obtrusive enemies, and so forth. Sea-urchins move by means of long protrusible suctorial tube-feet, supplied with water from five water-vessels on the interior of the wall of the test, along five radiating (ambulacral) areas. But movement is helped by the mobile spines, and the common sea-urchin is known to hobble along on the tips of five strong teeth which project out of the mouth. This mouth is usually in the centre of the ventral surface; the food-canal usually ends at the opposite pole in the centre of a complex 'apical disk.' The reproductive organs, in most cases five in number, corresponding to the general symmetry of the animal, lie underneath five plates of the apical disk, through holes in which the egg-cells and sperm-cells pass into the water. As in almost all Echinoderms, the fertilization of the eggs is fortuitous in the water, but the ripening of the sex-cells is sometimes periodic, at full moon, and when one sea-urchin begins to 'spawn' its neighbours follow suit. Thus the fortuitousness is lessened. The free-swimming larva is a *Pluteus*, like that of brittle-stars, and the whole of the complex edifice of the adult shell can be traced back to three-rayed spicules of limestone in the Open-Sea larva. Examples: the common sea-urchin (*Echinus*); the heart-urchin (*Echinocardium*); the purple heart-urchin (*Spatangus*); the flexible urchin (*Phormosoma*); the big-spined urchin (*Cidaris*); the minute *Echinocyamus*, like half a green pea.

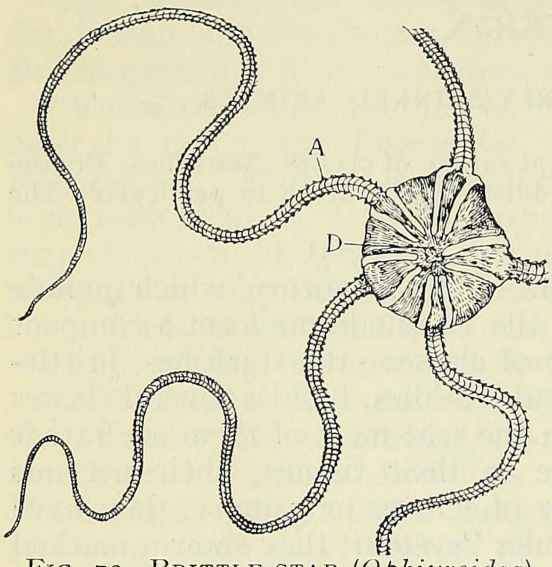


FIG. 73. BRITTLE-STAR (*Ophiuroidea*)
A, arm; D, disk seen from dorsal surface.

(*d*) **Sea-cucumbers** or **Holothurians.** The popular name of this class of prickly-skinned animals indicates the general appearance of the larger ones; but our picture of a sea-'cucumber' must include five feathery and mobile tentacles at one end. Some Holothurians are like plump worms; others creep about on a flattened sole and remind

one of sea-slugs. Of the great majority it may be said that they are more muscular and less calcareous than most other Echinoderms. The deposition of limestone usually takes the form of numerous platelets in the skin, and these are often beautiful, like anchors and wheels. Sea-cucumbers feed on minute animals and organic particles from the sand. In some cases these are caught by the waving tentacles, which are then plunged into the mouth. The food-canal coils through the body, and near the posterior end there are sometimes strange organs (called Cuvierian organs) which eject long sticky threads, probably embarrassing to enemies. The black cucumber (*Holothuria nigra*) and some others do this so abundantly that they are called 'cotton-spinners.' A curious interrelation is that a little fish, called *Fierasfer*, often insinuates itself, tail first, into the end of a sea-cucumber's food-canal, and finds shelter there. This is what might be called a **shelter-association**, and may be further illustrated by a little fish (*Dasyprion*) that takes refuge inside a large sea-anemone, or various young fishes that shelter under Medusae (see MEDUSAE). As the last case shows, a shelter-association may readily come to have some connection with feeding, and thus point the way to parasitism. Thus the little pea-crab (*Pinnotheres pisum*), that is often found inside the Norway cockle (*Cardium norvegicum*), gets food as well as shelter there. It does not directly injure the cockle, but it nibbles at food that is being wafted along the gills. As already pointed out, the term **commensalism** (see INDEX) should be kept for external associations that are *mutually beneficial*, as in the case of hermit-crabs and their partner sea-anemones. It may be useful to bring these various linkages together again in a summary:

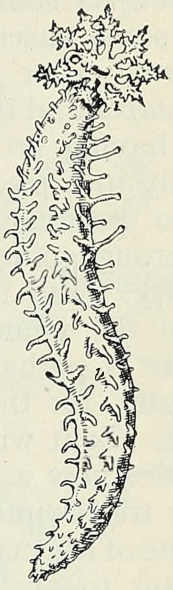


FIG. 74.
THE HOLOTHURIAN KNOWN AS THE SEA-GHERKIN (*Cucumaria saxicola*)

(1) One animal merely growing on another, like an acorn-shell on a scallop (*epizoic* relation).

(2) One animal sheltering in another, like the *Fierasfer* inside the sea-cucumber (*shelter-association*).

(3) An animal getting food as well as shelter, like the pea-crab on the cockle.

(4) A one-sided association, injurious to the host, as in parasites and internal predatory animals.

(5) A mutually beneficial external partnership or *commensalism*, like hermit-crab and sea-anemone.

(6) A mutually beneficial internal partnership, like the green Algae inside the inner cells of *Hydra viridis*, this being called 'symbiosis' in the strict sense.

When a sea-cucumber is molested it may over-contract its muscles and eject some of its internal organs—a very drastic proceeding, but in some cases probably life-saving. What is jettisoned can be re-grown, after the usual fashion of Echinoderms. In the worm-like *Synapta* and its relatives, which differ from the ordinary sea-cucumbers in having no tube-feet, there is remarkable readiness to break the body into pieces. As in most Echinoderms, the eggs usually develop into peculiar free-swimming larvae, which pass through a very thoroughgoing change before they settle down and assume the adult shape. But in some cases the free-swimming larval stage is skipped and the young are sheltered in a variety of ways by the mother. This is perhaps the lowest level at which a kind of **parental care** occurs, for the mother sea-cucumber may carry fully-formed young ones about with her for a considerable time. It is also interesting to notice how a whole chapter in the ordinary life-history—in this case the free-swimming larval stage—may be suppressed when the conditions of life make this advantageous. Holothurians occur from shallow water to great depths, and it is very striking to find a delicately built, transparent, free-swimming form, called *Pelagothuria*, which lives in the Open Sea. This illustrates the way in which living creatures often find out possibilities which one would have been inclined to regard as impossible.

(*e*) **Feather-stars, Sea-lilies,** or **Crinoids.** Somewhat apart from other Echinoderms are numerous *stalked* forms—stalked during their whole life in most cases, but sometimes only in their youth. Most of these stalked forms (e.g. *Cystoids* and *Blastoids*) are long since extinct, and form four classes that have no living representatives to-day. The only class that has living representatives is the class of Feather-stars or Crinoids, and many members of the class are only known as fossils. Thus we have here to do with a *dwindling group* of animals.

In deep water there are permanently stalked feather-stars, animals of great beauty, which sometimes live together in large numbers, like daffodils by the lakeside. There are ten feathery arms, and in the cup where these meet there is an upward-turned mouth. The centre of the down-turned dorsal surface is supported on the top of a long jointed stalk which is anchored by root-like processes to the floor of the sea. The tube-feet are small and serve chiefly for wafting minute organisms to the central mouth. In some ways the feathery arms may be compared to a net that catches food for itself and for the rest of the animal.

The rosy feather-star (*Antedon bifida*), not uncommon at depths of ten fathoms or so off some British coasts, is stalked in its early life, after it settles down from its free-swimming first larval stage, but when it attains a certain size it breaks away from its moorings, and swims about in a gentle way by expanding its feathery arms and drawing them inwards again. On the centre of its down-turned dorsal surface there is a knob which represents the broken-off top of the stalk or 'stem'; and this knob bears a number of curved grappling outgrowths, called *cirri*, by which the rosy feather-star fixes itself to stones and the like on the floor of the sea. Where the arms meet is the main body of the animal, a flat cup or 'calyx,' containing most of the organs that are usually found in Echinoderms. But the reproductive organs lie in the short branches or 'pinnules' of the arms, and during the earliest stages of development the eggs adhere to the skin. A free-swimming stage develops into a minute barrel-shaped larva with hoop-like bands of locomotor cilia. After a short time this settles down and develops a stalk. Thus the young form of the free Antedon is a fixed and stalked animal, just as the great majority of Crinoids are throughout their life. The young Antedon is showing, no doubt, the habit of its ancestors; and this is called **recapitulation.** For it is a common feature among animals that the individual development should show in condensed form some indication of the evolution of the race. But the recapitulation is often much telescoped and disguised. Since a good living representative of the permanently stalked feather-stars is called *Pentacrinus*, the youthful fixed form of Antedon is described as the Pentacrinoid stage. These Crinoids represent a very ancient stock, for they were at their climax in the time of the Coal Measures (Carboniferous) many millions of years ago. They have been dwindling in numbers ever since, but they still have a strong hold, especially in the retreats of the Deep Sea.

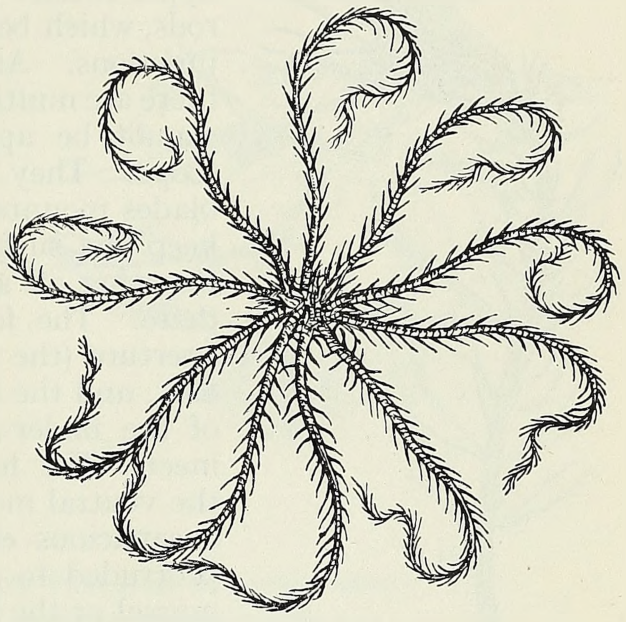


Fig. 75. A Feather-star (*Crinoidea*)

THE STARFISH IN PARTICULAR. — One of the commonest British starfishes is called *Asterias rubens*, a slowly moving, five-rayed flattish

star. It pulls itself laboriously along the floor of a shore pool, or up the rocky side, and if we try to lift it very gently we find that it adheres to the surface on which it was creeping. It does this by means of scores of suckers or 'tube-feet' which lie along a deep groove on the under-side of each of the five arms. The upper-surface shows a network of little rods, which bear short blunt spines at their junctions. At the bases of these spines there are multitudes of minute pincers which cannot be appreciated without a microscope. They have a couple of snapping blades mounted on a basal piece, and they keep the surface of the starfish clean by throwing off anything that tries to anchor there. The food-canal ends in a minute aperture (the anus) near the centre of the disk, and the large mouth is on the middle of the under-surface where the five arms meet. The food-canal that runs between the ventral mouth and the dorsal anus has a capacious elastic stomach which can be protruded to surround and engulf a small mussel or the like; and into each arm there pass two somewhat feathery extensions of the stomach, which serve for digesting and absorbing the food. On the upper-surface between two of the arms there is a somewhat conspicuous plate with numerous grooves. Because its texture has a slight resemblance to a miniature madrepore-coral, it has received the rather absurd name 'madreporite'; the grooves lead the water by means of very minute lashed (flagellate) canals into the hydraulic (**water-vascular**) system by means of which the starfish moves.

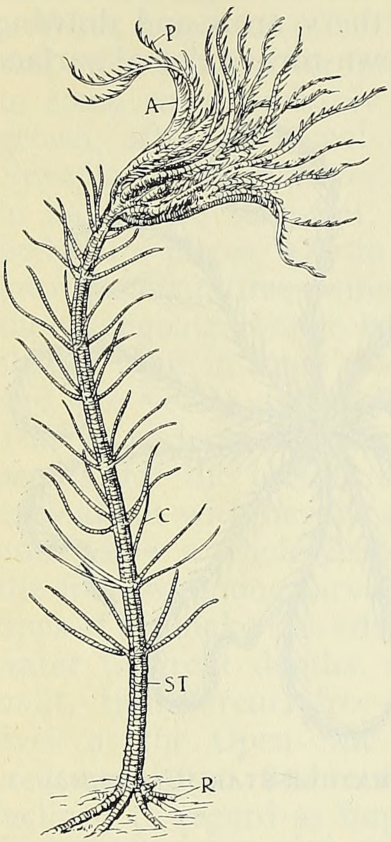


FIG. 76. GENERAL APPEARANCE OF A STALKED CRINOID OR SEA-LILY (*Pentacrinus*) A, pinnate arm; C, cirri arising in whorls from the jointed stem (ST); P, pinna; R, attaching root-cirri.

The under-surface bears the numerous tube-feet in the five deep and crowded grooves, called **ambulacral grooves**—a word that seems to mean locomotor. All the tube-feet are sensitive, and at the base of the tube-foot at the very tip of the arm there is a cushion with minute red pits which form an 'eye.' Though it is not able to form an image, it is sensitive to light. In the middle of each groove there is a ridge of nerve-cells and nerve-fibres, and the five strands unite in a circle or pentagon around the mouth. If we bend the arm of a dead

starfish between our thumbs along the line of the tube-foot groove, we can see this nerve-strand as a slender thread. It is a good illustration of a very simple type of nervous system, for there are no nerve-centres or ganglia, and the cords are hardly separated from the skin. All over the surface of a starfish there is a network of

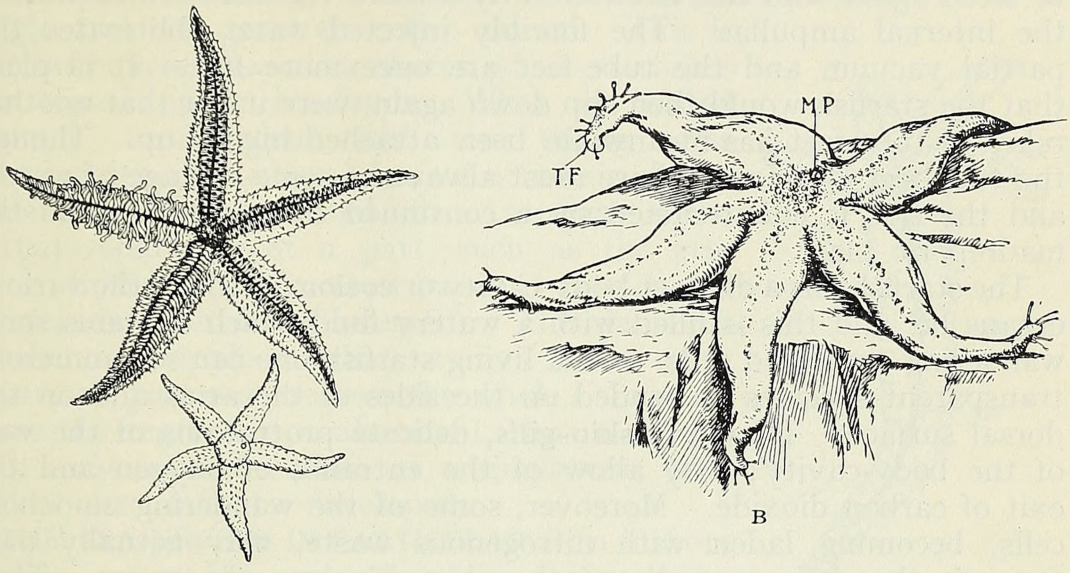


FIG. 77. COMMON STARFISH (*Asterias rubens*)
A. Upper and lower surfaces, showing tube-feet.
B. Shows madreporic plate (MP), and tube-feet (TF).

nerve-cells just below the transparent outer skin (or *ectoderm*). But the starfish gets on wonderfully well without brains, for it can move in a definite direction, it can attack a small sea-urchin with success, and it can right itself if turned upside down. It is the nerve-ring around the mouth that enables it to order (or *co-ordinate*) its movements in an effective way.

How does a starfish creep up the side of a shore pool? Water enters by the madreporic plate, passes down a curiously twisted, filter-like flagellate ' stone-canal ' into a circular water-vessel around the mouth. Thence the water passes by a radial vessel up the groove of each arm, and is led into the numerous suckers or tube-feet. Each tube-foot is continued inwards into an internal muscular bulb or *ampulla*. These little bulbs behave like syringes and when one contracts it drives water forcibly into its tube-foot. The tube-foot thus becomes tense, like a hose-pipe when water flows into it under pressure. The broad closed end of the tube-foot is pressed against the rock. A backward flow from the tube-foot seems to cause a partial vacuum to be formed at the tip, so that firm adhesion to the

rock is effected. This resembles the way in which the street-urchin's leather sucker adheres to the pavement. The next step is that the muscles in the wall of the tube-foot contract, and the starfish is pulled upwards. This recalls the way in which a ship is drawn close to the pier by the shortening of the hawsers. But the tube-feet must be freed again, and this is effected by a more vigorous contraction of the internal ampullae. The forcibly injected water obliterates the partial vacuum and the tube-feet are once more free. It is plain that the starfish would then slip down again, were it not that another relay of tube-feet has meanwhile been attached higher up. Though the tube-feet are closed, there must always be some leakage of water; and the loss is counteracted by a continued fresh supply from the madreporic plate.

The starfish has a distinct body-cavity or **coelom** in which the various organs lie, and this is filled with a watery fluid which contains some wandering amoeboid cells. On a living starfish one can see numerous transparent saccules protruded on the sides of the arms and on the dorsal surface. These are **skin-gills,** delicate protrusions of the wall of the body-cavity; they allow of the entrance of oxygen and the exit of carbon dioxide. Moreover, some of the wandering amoeboid cells, becoming laden with nitrogenous waste, may actually pass through the delicate walls of the skin-gills into the water. Thus there are very primitive respiratory and excretory systems. There are five pairs of reproductive organs, rather like elongated bunches of grapes, which lie in the cavity of each arm at the central end. The eggs are fertilized in the sea.

Animals are sometimes, and usefully, divided into **soft-mouthed** and **hard-mouthed.** The former have nothing in the way of jaws, and must therefore in most cases depend on minute particles or organisms or on very soft food. Now the starfish is a soft-mouthed animal, and yet it is carnivorous, often feeding on hard-shelled animals such as mussels. The explanation is to be found in the way in which the starfish protrudes its elastic stomach over a victim. A small mussel is often taken right into the stomach, where it dies and opens its valves. After the soft flesh has been digested the empty shell is ejected. But when the mussel is a large one, the method is necessarily different. The starfish hunches itself over its victim, folding itself like an umbrella, and pulls continuously with its tube-feet at the opposite valves of the shell. When the dying mussel gapes, the starfish intrudes its stomach and pours in digestive juices, so that the flesh is gradually dissolved and absorbed.

AUTOTOMY.—In the rough-and-tumble life of the shore, a starfish may have one of its arms pinned down by a loosened stone. Or some enemy like a large sea-snail may settle down on an arm and

refuse to be dislodged. In cases like this, it is possible for the starfish to separate off the damaged or threatened arm and escape with the rest of its body. This may be a life-saving sacrifice, for what has been snapped off can be regrown. The surrender is called self-mutilation or autotomy (*auto*, self; *tomia*, cutting), and it is sometimes (as in *Linckia*) a method of asexual multiplication. For a single arm can grow an entire animal. This is not infrequently seen on shores where starfishes are tossed up in hundreds. What are called 'comet' forms occur, with four young arms growing out at the basal end of a full-sized arm which had been separated off. Autotomy is the actual separation of a part, such as the arm of a starfish; but in most cases it is followed by **regeneration** or replacement. The damaged whole may replace what it has lost; or a separated part may regrow the whole. In some cases the regrowing is abnormal; thus a double arm may take the place of a single one, or a forked arm may be developed.

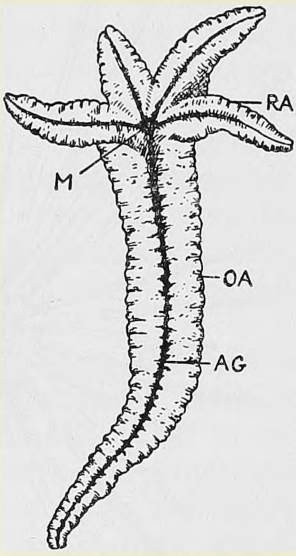


FIG. 78. ONE ARM OF STARFISH REGENERATING LOST ARMS — THE SO-CALLED 'COMET' CONDITION

A G, ambulacral grooves; M, mouth; RA, regenerating arms.

THE SEA-URCHIN IN PARTICULAR.—In inshore waters, among the seaweeds, various sea-urchins, such as *Echinus miliaris*, are common animals. They suggest at first glance a small rolled-up hedgehog, so thickly are they covered with movable spines. Their movements are slow, and some kinds ensconce themselves in holes which they are able to excavate in the rock.

Like the starfishes, they move by means of the adhesive tube-feet, which can be elongated far below the spines; but they are also helped by the spines themselves, which are swayed about by muscles on their ball-and-socket basal joint. When the spines are rubbed off, the balls or knobs are seen all over the shell, or **test**, as it is often called. But, as we have mentioned, there is a third and quite unique kind of movement, which is sometimes to be seen on a flat surface of firmly caked mud, and can be studied in an aquarium by getting the sea-urchin to move over a slab of plasticine. Out of the mouth project the tips of the five teeth of a remarkable chewing arrangement called 'Aristotle's lantern,' which can be swayed about from side to side by powerful muscles. When the lantern is swayed the teeth act like little levers, and the sea-urchin tumbles along or hobbles along from one position to another, the teeth always downwards. On the flat plasticine one sees the marks of the

five teeth, then an interval, then the five marks again, then an interval, and so on. In the intervals between the tooth-marks may be seen the minor pinprick-like marks of the spines.

Sea-urchins browse on 'acorn-shells' (rock-barnacles) and other small sedentary animals; they also eat certain seaweeds and seem to swallow some mud for the sake of the organic matter it contains. One would not expect them to have many enemies of their own, but starfishes sometimes tackle small sea-urchins and succeed in mastering them. Large sea-urchins are sometimes seen exposed for sale in the fish markets of Mediterranean towns, the edible parts being the spongy reproductive organs which hang down internally from the top of the shell. The beautiful tests are sometimes scraped thin and used as fancy globes for small table lamps.

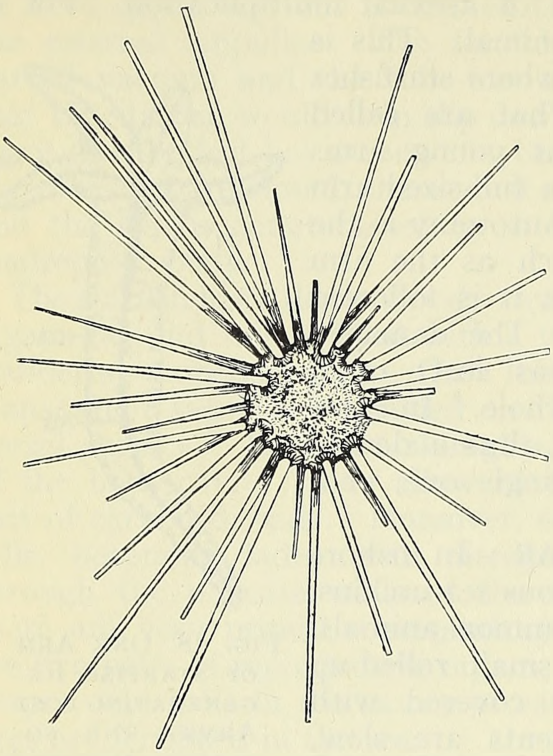


FIG. 79. SEA-URCHIN (*Echinoidea*) WITH LONG SPINES

The test is covered with **spines,** tapering to sharp points, and showing various sizes up to a limit. It is very interesting to see under the microscope a transparent cross-section of a spine, for it shows a very beautiful **zoned structure,** like the stem of a tree cut across. The concentric zones indicate periods of growth as line upon line of limestone was deposited. There is also in the common sea-urchin a marked economy of material, for the minute deposits of limestone are separated by minute empty spaces. Thus the spines do not usually become heavy, though there are exceptional forms, as in *Cedaris*, that cannot be called anything but massive.

Another interesting feature is the presence of numerous but inconspicuous snapping spines or *pedicellariae.* The largest are like three-bladed scissors mounted on flexible stalks, and the common sea-urchin shows three other kinds hidden among the ordinary spines. The uses of these little snapping spines are manifold. Some grip and throw off the larvae of animals that might settle on the test; others give a poisonous snap; others catch small particles and beat them to powder; others capture small useful animals and pass them on to the tube-feet which transfer them to the mouth. Yet all these

four kinds of snapping spines seem to be derivable from the ordinary type of spine, for the common sea-urchin shows intermediate gradations. All the kinds can be regrown if they are broken off, which is the only thing the sea-urchin can do in the way of **regeneration.** Here it should be noticed that there are some nerve-cells in the stalk of each pedicellaria which control its movements of bending and snapping. In the living sea-urchin a large snapping spine may be seen to bend away when one tries to grip it in the forceps. Each seems to be sufficient for itself and to act on its own. Amongst the spines, but firmly attached to minute bosses on the test, are glassy calcareous spheres like very small pinheads. They are called *sphaeridia* and the probability is that they are **balancing structures,** helping the sea-urchin to adjust its body to its own movements. Similar organs occur in many animals, helping in **equilibration.** Such, for instance, is part of the function of the three semicircular canals surrounding the inner ear in backboned animals.

At the lower pole of the sea-urchin's spherical shell there is a softish area about the size of a shilling on a big specimen. This is called the **peristome,** which means ' around the mouth,' and in its centre the five teeth of Aristotle's lantern may be seen projecting from the oral aperture. Close to the mouth are ten large but short tube-feet, used for tasting the food; there are also many small spines and snappers; beyond the periphery of the flexible peristome membrane there are ten branched gills. We mention these details because much can be easily seen on a living sea-urchin in a glass bowl; and it is a great pleasure to watch the various movements.

But to appreciate the intricate structure of the shell it is necessary to scrape off the spines and dry the scrubbed surface. At the lower pole there is the large circle of the peristome, so much larger than the mouth aperture by itself. At the other pole the round canal ends in the anus, which is surrounded by a somewhat pebbly **periproct.** Outside this there are five large genital plates, through which the egg-cells from a female or the sperm-cells from a male are shed periodically in the summer months. The largest of these plates is perforated by numerous minute apertures, suggestive of the rose of a watering-can. It is called the madreporic plate, because (p. 174) its texture is just a little like the surface of some madrepore corals; and it serves for the entrance of the water that works the hydraulic **tube-foot** system. Fitting into the corners outside the five genital plates are five ' ocular ' plates, each with an aperture for a sensitive pigmented tube-foot. In some sea-urchins there are eye-spots in this position, but not in the species we are describing. The tube-feet that protrude through the ocular pores are not in any special way sensitive to light; but the whole transparent skin has this property.

The periproct and the ten plates outside it form what is called the **apical disk.** If we start from this and draw a pencil from one of the five ocular plates downwards to the other pole, we traverse a double row of narrow plates that carry spines and the apertures for the tube-feet. This is called a radial or **ambulacral area,** and it is useful to hold a dry and scraped test against the light and look through the peristome, for then we see very clearly the multitude of little pores through which the tube-feet are connected with the internal radial water-vessel and the associated bladders or ampullae. If we start again at the upper pole, but with a genital plate this time, our pencil traverses a double row of broad plates which carry spines only. This is called an **inter-ambulacral area.** It follows then that there are twenty vertical rows of calcareous plates running from the aboral towards the oral pole, stopping short at the outer margin of the peristome. The whole test is covered with ciliated, transparent, tissue-paper-like skin, so the skeleton is not so external as it looks. Between the plates and on their internal surface there is delicate transparent connective tissue, which is able to add to the size of the plates by depositing more limestone around the margin of each. There is also a formation of new plates outside the apical disk. Thus as the soft internal parts of the animal grow, there is a proportionate increase in the size of the shell. A very notable achievement is Dr. Isabella Gordon's description of the entire upbuilding of the sea-urchin's complicated edifice, starting with a few triradiate spicules of limestone in the free-swimming larva.

In the service of the mouth is **' Aristotle's lantern,'** which the great philosopher saw more than two thousand years ago. In shape it is like the old-fashioned type of lantern that the night watchmen used to carry upright on the end of a long handle. There are five teeth in five sockets, and fifteen other pieces, so it is a very complicated structure. It corresponds to a relatively simple skeleton that supports the mouth region in sea-cucumbers, and it is absent in all the heart-urchins except one (*Echinoneus*). It is swayed about, with a slightly rocking movement, by powerful muscles which are attached to croquet-hoop-like standards rising internally from the test just beyond the peristome margin. Pieces of seaweed and the like get in between the points of the teeth and are torn up by the rocking movements, and it may be noticed that the teeth are always growing at their internal ends, at the top of the lantern, as they get worn away at their tips. We have mentioned that the lantern helps in locomotion—the sea-urchin being unique in hobbling along on the tips of its teeth !—and it is said that the rocking of the lantern also helps in keeping up water-currents useful in aëration. We have lingered over the sea-urchin's test, for it affords such a fine lesson in intricacy.

There is no difficulty in getting good dried specimens, and there is great gain in verifying all the details. It is a discipline in precision, and without precision there can be no firm grip of Natural History.

There is a nerve-ring round the mouth and a branch up each ambulacral area, but the sea-urchin is in a strict sense a brainless animal. Widely scattered and forming a network are numerous nerve-cells, sometimes in little groups, which superintend the movements of tube-feet and snapping blades, and so forth, so that there is a continual occurrence of **reflex actions** of a simple kind. The wonder is that so many self-governing parts work so harmoniously, but there are detailed arrangements which help this. Thus there is a chemical substance in the outer skin which paralyses the muscles of the snapping blades so that they will not bite one another or the tube-feet.

The food-canal passes up through the lantern, winds two and a half times round the inside of the shell, and ends at the upper pole. If one inserts one's finger into the peristome of a dried shell one is demonstrating the large **body-cavity** or **coelom.** During the animal's life it is filled with a fluid containing cells with a **respiratory pigment** (*echinochrome*) that is able to capture oxygen. But this body-cavity (or perivisceral) fluid is quite different from the blood, which is not easily traced in the sea-urchin.

The water that works the hydraulic locomotor (water-vascular) system enters by the madreporic plate, passes down a membranous stone-canal (calcareous in *Cidaris*), which enters a circular canal around the top of the lantern. From this there proceed five radial vessels, one up each ambulacral area, which give off little reservoirs or ampullae internally and tube-feet externally. At the end of each tube-foot there is an adhesive disk supported by a beautiful rosette of calcareous platelets. There are branched skin-gills around the outside of the peristome, and both the water-vascular system and the body-cavity help in respiration. There is no hint of kidneys. The nitrogenous waste-products must simply diffuse out.

The sexes are separate and indistinguishable externally. The ovaries or the testes, as the case may be, hang down under the apex of the shell, and the egg-cells or sperm-cells pass out at the genital pores. In some species, though not in *Echinus esculentus*, there is lunar periodicity in the emptying and refilling of the gonads. The fertilized eggs develop into free-swimming pelagic larvae, which undergo a striking metamorphosis into minute sea-urchins.

CHAPTER XI

CRUSTACEANS

The great group or phylum of Jointed-footed Animals or Arthropods—Characteristics of typical Arthropods—Characteristics of typical Crustacea—Survey of Crustaceans—Some notable Crustaceans—Larval Crustaceans—Natural History of Crustaceans.

The Great Group or Phylum of Jointed-Footed Animals: Arthropods

This is the largest group in the animal kingdom, for it includes Insects, and there are more species of insects than of all other animals taken together. Besides Insects, the Arthropods include Crustaceans, Myriapods, Spiders, and King-crabs, and several smaller divisions. There must be far over a quarter of a million different kinds of Arthropods.

CHARACTERISTICS OF TYPICAL ARTHROPODS.—If we exclude primitive, parasitic, and degenerate Arthropods, we may sum up the characteristics thus:

(1) The body is bilaterally symmetrical, and consists of numerous rings or segments.

(2) The appendages or limbs are jointed, an advance on the unjointed limbs of sea-worms; and some of these appendages are in the service of the mouth as jaws.

(3) The skin is covered with a non-living cuticle of chitin or of chitin plus limestone; and this has to be periodically moulted as long as the animal continues to grow larger.

(4) The nervous system is of the Annulate type, similar to that in Annelid worms, i.e. there is a dorsal brain, a ventral chain of ganglia, and a ring round the gullet connecting the two.

(5) There is usually a highly developed muscular system, with numerous separate muscles, composed of finely cross-striped, quickly contracting fibres; most Arthropods are very active animals.

(6) The true body-cavity or coelom is always much reduced in the adult; the apparent body-cavity (or *haemocoel*) contains some of the blood; the heart lies dorsally above the food-canal; there are very rarely any ciliated cells.

(7) There is frequently a metamorphosis in the course of development; thus out of the crab's egg there comes a larva entirely different from the adult, and out of the butterfly's egg there comes a caterpillar.

CHARACTERISTICS OF TYPICAL CRUSTACEANS.—We begin with one of the large classes included in the phylum Arthropods—the class **Crustacea.** It is represented by crabs and lobsters, shrimps and prawns, barnacles and 'water-fleas.' If we exclude primitive, parasitic, and degenerate forms, we may sum up the characteristics thus:

(1) With few exceptions, such as land-crabs and wood-lice, crustaceans live in water, and breathe either by gills or through the skin (cutaneously).

(2) The cuticle includes calcium carbonate as well as chitin.

(3) The typical appendage consists of two branches or blades (bi-ramose) springing from a basal piece.

(4) The head carries two pairs of antennae in addition to other appendages, such as at least three pairs of jaws (insects have one pair of antennae; spiders and scorpions and mites have none).

(5) The second region of the body, the thorax, which is sometimes distinct from, and sometimes fused to the head, bears various kinds of limbs, such as four pairs of walking legs in the case of a crab.

(6) A third region of the body, the abdomen, is often well defined and often carries appendages, such as the swimmerets of a lobster.

(7) There are often free-swimming larval stages very different from the adult forms.

SURVEY OF CRUSTACEANS.—First, we may distinguish the Lower Crustaceans (**Entomostraca**), such as water-fleas and barnacles, from the Higher Crustaceans (**Malacostraca**), such as crabs and lobsters, shrimps and prawns, sand-hoppers and wood-lice. The contrast may be stated, as is always most convenient, in parallel columns:

Lower Crustaceans	Higher Crustaceans
Usually small and comparatively simple.	Usually larger and more complex.
The number of segments and appendages is very diverse.	The head consists of five, the thorax of eight, and the abdomen of six (in *Nebalia*, etc., seven) segments.
The larva is usually hatched out as an unsegmented *Nauplius*.	The larva is usually hatched out at a higher level, e.g. a *Zoaea*.
There is no gastric mill.	There is often a gastric mill.
The kidney organs are associated with the second maxillae.	The kidney organs of the adult are usually associated with the antennae, but maxillary glands may be present in the larva and occasionally persist in the adult.

Lower Crustaceans or Entomostraca

Order 1. **BRANCHIOPODS** (i.e. gill-footed), with at least four pairs of leaf-like swimming appendages bearing respiratory plates. The body is protected by a shield-like or bivalve shell.

(*a*) **Phyllopods.** The longish body has many segments with leaf-like appendages; the shell is rarely absent, usually shield-like or bivalved. Here are included the beautiful *brine-shrimps* (*Artemia*), e.g. *Artemia fertilis*, one of the four animals able to survive in the briny waters of Great Salt Lake. For long periods the brine-shrimps may show **parthenogenesis** or virgin birth; that is to say, the egg-cell develops without being fertilized by a sperm-cell. This is not uncommon among the lower crustaceans. Another well-known Phyllopod, which means 'leaf-footed', is *Apus*, a giant among the lower crustaceans, for it is over an inch in length. It has an almost world-wide distribution. On its abdomen there are as many pairs of appendages as there are weeks in the year.

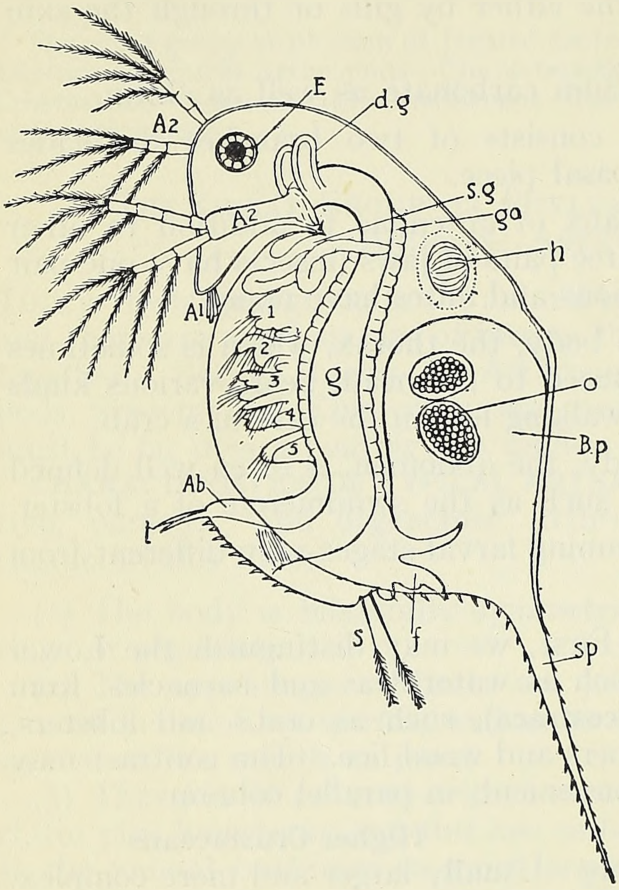


Fig. 80. The Water-flea (*Daphnia*)

E, eye; A2, second antennae; A1, first antennae; *dg*, digestive caeca; *sg*, shell-gland; *go*, gonad; *h*, heart in pericardium; *o*, ovum; *Bp*, brood-pouch; *sp*, spine; *f*, furca; *s*, setae; *Ab*, rudimentary abdomen; *t*, caudal fork; *g*, gut; 1–5, thoracic limbs.

(*b*) **Cladocera.** Small, short-bodied, laterally compressed '*water-fleas*,' with few and somewhat indistinct segments; there are never more than six pairs of thoracic limbs; the shell is usually bivalved and the head often projects freely; the most important swimming organs are the second antennae; the females show a brood-chamber between the shell and the back. The largest Cladoceran (*Leptodora hyalina*) is three-fifths of an inch in length; many of them can swim through the eye of a sewing-needle. Parthenogenesis is common and may be continued through many generations, but there are well-protected

'**winter eggs**' or resting eggs which require fertilization. Among the commonest animals in fresh water are species of the little water-flea *Daphnia*. Among the many others are *Moina*, *Sida*, *Polyphemus*, *Leptodora*, and *Simocephalus*. There are many in the sea, often forming a large part of the floating **Plankton** on which larger marine animals feed.

Order 2. **OSTRACODA.** Small 'water-fleas' in fresh water and in the sea, the body with about eight segments completely enclosed in a bivalve shell. There are seven pairs of appendages. There is no heart. The development is direct, i.e. out of the egg there comes a miniature Ostracod. Parthenogenetic generations may succeed one another for a long time. Common freshwater forms are species of *Cypris* and *Candona*; common marine forms are *Cythere* and *Cypridina*. The last is a good example of an active pelagic animal with notable *luminescence*. The production of the light has been carefully studied in this case, and it seems to be due, as in fire-flies and the boring *Pholas*, to the fermentation of a protein-like substance, *luciferin*, by an enzyme, *luciferase*. The light is cold light, without any heat rays. It is difficult even to suggest what use the luminescence (badly called phosphorescence) can possibly be to the little Cypridinas.

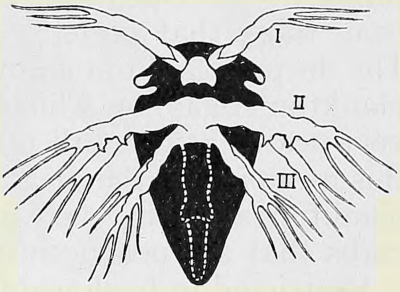


FIG. 81. THE NAUPLIUS LARVA OF A CRUSTACEAN
I, first pair of appendages (unbranched); II, III, second and third pairs of appendages; these are bi-ramose swimming organs.

Order 3. **COPEPODA.** This is a large order of small crustaceans, abundantly represented in the sea and in the fresh waters, while not a few are parasitic. There are about sixteen segments; most of the appendages are of the two-bladed (bi-ramose) type; there is no true shell or carapace. The larva is usually a **Nauplius**, an unsegmented little creature with three pairs of appendages and a median eye.

The sea is sometimes blood-red with thick swarms of *Calanus*, almost all females, which form an important part of the food of pelagic fishes. Like many related forms, they show greatly elongated bristles which increase the floating power of these drifting animals. When there is more floating and drifting in the open waters, the term **Plankton** is used; when there is more swimming, the term **Nekton** is better; and it may be convenient here to take a general view of marine animals:

Marine Animals

Pelagic, in the open waters away from the shore, e.g. Jellyfishes, Herring, Whales.

Littoral, in shallowish waters, well-lighted, with seaweeds growing, e.g. Sea-anemones, Crabs, Limpets.

Abyssal, in deep, dark waters, where there are no plants, e.g. Venus's Flower Basket, Sea-lilies.

The same grouping serves, of course, for the animals of a deep lake.

Then if we focus attention on pelagic or Open-Sea animals, we may distinguish the swimmers (Nekton) and the drifters (Plankton); and these may be further grouped according to size. A huge jellyfish, with a disk a yard across, may be taken as a representative of the *Macro*-plankton, while a little Copepod, the size of a pin's head, belongs to the *Micro*-plankton. To still minuter organisms, such as many Infusorians, that are able to get through the invisible gaps in fine tow-netting silk cloth, the term *Nano*-plankton, which means dwarf plankton, has been applied. It is also of importance to distinguish the Open-Sea animals that keep near the sunlit surface from those that prefer a lower level where the light is fading away. The deeper plankton animals have a quieter life, but the all-important plankton Algae, on which pelagic animals ultimately depend, become very scarce at a depth of a few fathoms from the surface. To finish this grouping in the meantime, it is useful to distinguish permanently plankton animals, such as *Calanus*, from the larvae of, say, shore-crabs that are pelagic in their youth only.

Restricted to fresh water, but common everywhere, are many species of a Copepod called *Cyclops*. They are only the size of a pin's head; the giant's name that they bear refers to the single median eye. Many Copepods have become parasitic, especially the females, and are popularly called '**fish-lice.**' They are often seen hanging on to the skin and gills of fishes. The female of a common one, *Lernaea branchialis*, occurs on the gills of the haddock, and shows a strangely deformed body, quite unrecognizable as a Copepod, a Crustacean, or an Arthropod. The head-end is so deeply embedded, bearing branched blood-sucking processes, that it is difficult to extricate the animal. At the other end of the ugly body are two coiled egg-sacs. We use the word 'ugly' with deliberation, for it is only among parasitic (or over-fed domesticated) animals that an unpleasing deformity of body occurs. Ugliness is a brand of degeneracy, but the term should never be applied to merely grotesque creatures, such as bats or chamaeleons.

Order 4. **CIRRIPEDIA** (*cirrus*, curl; *pes*, foot): curl-footed crustaceans, namely Barnacles and Acorn-shells. The ship-barnacle (*Lepas anatina*) is attached as an adult to floating logs and even to ships. A bunch has actually been found fixed to the flattened tail of a sea-snake. At the free end of the barnacle's flexible stalk, often six inches

in length, the rest of the animal dangles, enclosed in five shell-valves, somewhat suggestive of a pea-flower. The stalk contains a cement gland and the much-branched ovaries, and the stalk itself is made of the front region of the head, including the first pair of feelers. From between the two paired shell-valves there protrude six pairs of two-branched, curl-like thoracic limbs, which waft minute animals into the mouth. The sexes are combined; the liberated eggs are often seen as flat cakes between the body proper and an external fold of skin that lines the shell. Out of the eggs come free-swimming larvae (nauplii), which moult several times and become like little Cyprids. These fix themselves and undergo a metamorphosis, lasting until the adult form has been established.

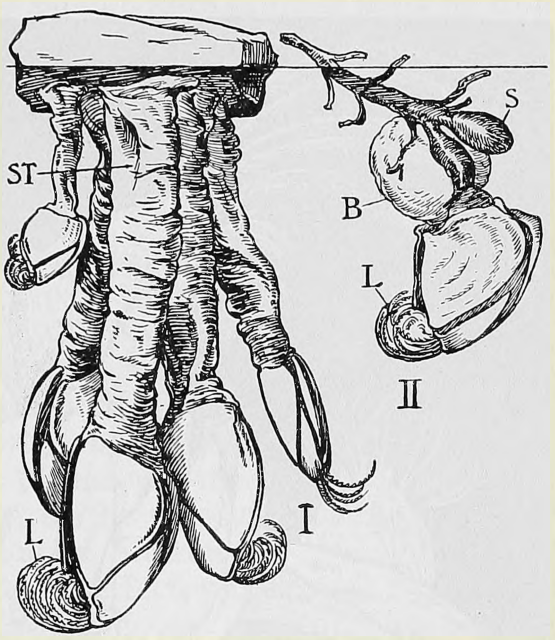


FIG. 82. BARNACLES

I. Ship-barnacle (*Lepas anatina*). ST, flexible stalk; L, curled limbs.

II. Floating barnacle (*Lepas fascicularis*) attached to a floating piece of seaweed (S), which its increasing weight is dragging below the surface. B, gelatinous buoy, secreted by the barnacle, enabling it to continue floating.

Another species, the 'floating barnacle' (*Lepas fascicularis*), illustrates very well what is meant by an **adaptation,** a special adjustment of structure or habit that suits some particular condition of life. The free-swimming larva of this species fastens itself to some small floating object, such as a piece of seaweed or a gull's feather. So far, so good, but as the barnacle grows, it becomes too heavy for its float. Now one adaptation to prevent it sinking below the surface zone where food is to be found, is its lightness of build. The valves of the shell have very little limestone. But a second adaptation is that in the region of the short stalk there develops a buoy of chitin mixed with gas-vacuoles. This keeps the 'floating barnacle' from sinking.

Another interesting kind of barnacle is *Scalpellum,* with various species usually found attached to Deep-Sea animals. (*a*) Some species, like *Scalpellum balanoides,* are cross-fertilizing hermaphrodites, as is the case with the ship-barnacle. (*b*) In most species, e.g. *Scalpellum vulgare,* the hermaphrodites carry a number of pygmy males, which Darwin called **complementary males.** (*c*) In a few cases, such as *Scalpellum regium,* the sexes are separate, but while the females are of ordinary dimensions, the males are pygmy parasites.

THE BARNACLE MYTH.—On our holiday we found on the seashore near the Giant's Causeway a bulky piece of jetsam that we would fain have carried home. It was a log of wood about the length of a railway sleeper, covered on one side with a dense growth of ship-barnacles. At the end of each flexible stalk, nearly four inches long, there dangled the enshelled animal, and from some valves that gaped there protruded the six pairs of two-branched and bristly limbs which waft the microscopic food into the animal's mouth. These limbs definitely betray the crustacean character of the barnacle, which is well masked by the somewhat mollusc-like shell. In two famous papers, in 1830 and 1835, Dr. J. Vaughan Thompson, of Cork, cleared up the zoological puzzle of barnacles, the first paper, as its title says, 'demonstrating their deceptive character, the extraordinary metamorphosis they undergo, and the class of animals to which they indisputably belong'; the second paper 'completing the Natural History of these singular animals, and confirming their affinity with the Crustacea.' As we have said, the eggs of barnacles give rise to minute free-swimming larvae (nauplii) which pass through two other stages, and then attach themselves by their head-end and undergo a remarkable transformation which suits them for their fixed life. We have already said enough about the animal, and turn now, for a change, to its myth, utilizing a learned and humorous book by Edward Heron-Allen, F.R.S., entitled *Barnacles in Nature and in Myth* (Oxford University Press, 1928).



FIG. 83. ROCK-BARNACLES

In circumstantial statement the barnacle myth is first found in the manuscript of Neckam (d. 1217), who describes how 'bernekke birds' come out of pinewood steeped for a long time in the sea. In 1187 his contemporary Gerald de Barri, otherwise known as Giraldus Cambrensis, narrates that in Ireland there are bernacae, smaller than

marsh geese, which are produced from fir timber tossed along the sea, and are at first like gum. 'Afterwards they hang down by their beaks as if they were a seaweed attached to the timber, and are surrounded by shells in order to grow more freely'(!) They develop a strong coat of feathers, and either fall into the water or fly freely away into the air. Giraldus goes on to say that he had frequently seen more than a thousand of these small bodies of birds hanging from a piece of timber on the seashore. As the birds in question, called vernicle geese, do not nest or lay eggs, they are eaten by religious men in some parts of Ireland at the time of fasting, for 'they are not flesh nor born of flesh.' There is no doubt that Giraldus was familiar with ship-barnacles, and believed that they turned into goose-like birds.

About the same time, in the *L'ymage du Monde* by Walter of Metz, there is the first record of another part of the myth that the birds grow on trees 'towards Ireland on the sea.' When they are nearly mature they fall off, and while those that fall on land come to nothing, those that fall into the water float away. It is subsequently pointed out by Vincent of Beauvais that the bernacas 'hang not from the ends of the branches, but from the trunks and the bark.' This saving clause was not respected, however, in the woodcuts of the tree that began to appear after the invention of printing.

In the history of Scotland written by Hector Boece (d. 1536) there is a record of two trees which bore young geese, 'some of them perfect-shaped fowls'; but he makes a point of the fact that these trees were washed in from the sea. 'Some people believe that the claiks grow on trees by their beaks, but their opinion is vain.' Boece was positive that the geese arose only on trees, timber, and even fruits that had floated about in the sea. From this and other references it is plain that the association of the geese or the barnacles with trees growing on land was a secondary and wanton embellishment, suggested by the growth of barnacles on trees flooded out to sea and on flotsam seaweed, and was perhaps confirmed by the resemblance of a ship-barnacle to an unopened pea-flower. There are five petals and there are five shell-valves; what more is required?

The difficulty is to understand how able-minded and not altogether unobservant men could assert that they saw young geese inside the shells of barnacles, and how the confusion should have lasted so long. For, although the myth was punctured by Albertus Magnus (d. 1280), who said that he and his friends had seen the barnacle goose lay eggs, we find that as late as 1661 Sir Robert Moray read a paper before the Royal Society describing the 'perfect sea-fowl' within the valves. Indeed, in spite of numerous protests, the story received wide credence till the middle of the eighteenth century, when most people began to

be thoroughly ashamed of it. In explanation, it has been suggested that the breeding-places of the barnacle goose in Spitsbergen and East Greenland were not known (*pace* Albertus Magnus) till the twentieth century, and that the life-history of the barnacle was not known till 1830. Both creatures were mysterious in origin. But there were many such gaps in knowledge during the centuries when the barnacle myth was flourishing. It has also been pointed out that the ship-barnacle is a quaint creature, not readily classified, yet common enough and striking enough to demand some theory. Moreover, the six pairs of feet are to the prejudiced eye a little like feathers, and, according to Mr. Heron-Allen, it was from this slender foundation that the myth arose. He is certainly right to discard entirely a philological theory that two similar words of different origin, ' bernicle ' for the bird and ' barnacle ' for the crustacean, became mixed up so persistently that people had perforce to give the creatures themselves a genetic affiliation.

Perhaps there is a fallacy in trying to explain, to our modern minds, how a confusion characteristic of the Dark Ages could arise and persist. For during that long vicious parenthesis men had lost the ambition to face facts for themselves and to verify by direct scrutiny; they relapsed into magical and superstitious ways of accounting for things. Moreover, belief in spontaneous generation was widespread, and if ' bees ' may arise from a lion's carcass, why may not the mysterious winter visitors called barnclakes (dark-coloured geese) arise from the mysterious bernaks on the timber jetsam?

But a very interesting corroboration of the theory that the myth arose from a fanciful clutching at a superficial resemblance is due primarily to the French zoologist Houssaye, who found on Mycenean pottery, perhaps 800 B.C., clear indications of the artistic transformation of a leaf into a bird and of a ship-barnacle into a goose. It looks as if the barnacle had made a deep impression on the artistic mind, but that what began as a drawing of a barnacle was conventionalized into a goose. Analogous cases to these ' barnaculized geese ' are well known to the historians of symbols. How dreadfully does knowledge hamper imagination! But we must not say more lest, to use Shakespeare's words, ' we shall lose our time and all be turn'd to barnacles.'

The **Acorn-shells,** such as the common *Balanus tintinnabulum,* form the familiar whitish encrustation over the rocks between high and low tide-marks. They resemble ship-barnacles in their general structure, but there is no stalk. They may be conveniently called rock-barnacles.

Huxley described a *Balanus* as a crustacean fixed upside down by its head, and kicking its food into its mouth with its legs. To appreciate this, one must peer into a rock pool to see the six pairs of two-

branched thoracic limbs sifting the water very elegantly, and wafting small organisms and organic particles into the mouth. The body is surrounded, as in the ship-barnacle, by a fold of skin which secretes two sets of calcareous plates: (*a*) an outer rampart of six or more vertical or sloping pieces, and (*b*) a fourfold lid which forms a roof to the rampart when the animal contracts. The roof of the rampart fits so precisely that a little water can be retained when the tide is out. Thus rock-barnacles between the tide-marks can continue living. In the shore pool one sometimes sees in spring a beautiful drifting object like a transparent curl, with twenty-four little hairs. This is a moult of the cuticle, and the hairs are the husks of the legs.

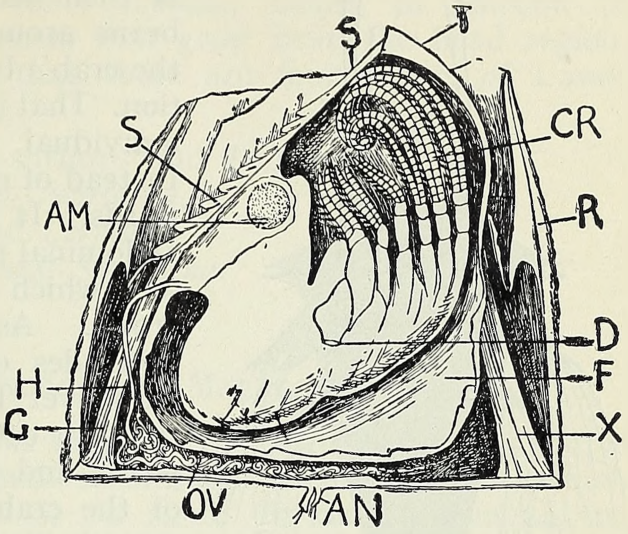


Fig. 84. Acorn-shell (*Balanus tintinnabulum*).—After Darwin

T, tergum; CR, thoracic legs; R, outer shell in section; D, aperture of oviduct; F, mantle cavity; X, depressor muscle of tergum; AN, antennae; OV, ovary; G, depressor muscle of scutum; H, oviduct; AM, adductor muscle of scuta; S, scutum.

The life-history of acorn-shells is like that of ship-barnacles; including (1) a minute free-swimming nauplius stage; (2) a bivalved Cyprid stage that settles down and fixes itself; (3) a fasting period of metamorphosis; and (4) the establishment of the adult features. Some acorn-shells fasten, not on rocks, but on molluscs and other animals, including whales.

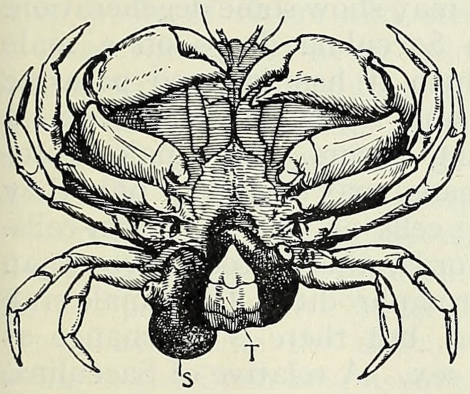


Fig. 85. The Parasite *Sacculina* (S) on the Abdomen (T) of a Female Shore-crab

SACCULINA.—Related to barnacles is one of the strangest of parasites, called *Sacculina*. It protrudes like a bean under the tucked-up tail of a shore-crab or an edible crab, and the projecting part contains the hermaphrodite reproductive organs, including a big brood-sac full of eggs. But from this sac numerous absorbing threads ramify through and through the crab and obtain nourishment. The life-history is striking, for this degenerate parasite starts from a free-swimming larva (nauplius)

which emerges with many others from the brood-sac. After a short time of growing, punctuated by moults, it becomes a Cyprid larva. It then fastens itself to the soft membrane around the base of a bristle on the crab's back, and undergoes **degeneration.** That is to say, it shows very marked individual simplification of structure. Instead of making progress, it goes backwards. It loses the thoracic and the abdominal parts; its head becomes a little sac, which sinks into the interior and grows. As it approaches maturity it protrudes on the under-surface of the crab; yet it is rather an endoparasite than an ectoparasite. It lives for three years, and during this time the growth of the crab is arrested. Moreover, the reproductive organs of both sexes of crab pass into a degenerate condition. The blood of the male crab appears to be altered profoundly by the parasite's requirements in the way of food, and the male begins to look more like a female. Thus the abdomen broadens and its appendages become a little like those which are used in the other sex for carrying the eggs. In the female crab these appendages may show some degeneration. Now if the Sacculina drops off a male crab, in which it has induced **parasitic castration,** and if the crab recovers, a strange thing occurs. The male reproductive organs may recover, but they produce egg-cells as well as sperm-cells. In other words, the reproductive organ becomes hermaphrodite. The female crab may recover, but there is no change as regards her sex. A relative of Sacculina, called *Peltogaster*, is a similar parasite on one of the hermit-crabs, but in this case the male crustacean shows egg-cells in the testes *before* the parasite is got rid of. There is no doubt that the male constitution is deeply altered towards femaleness by the influence of the parasite; and this suggests that the difference

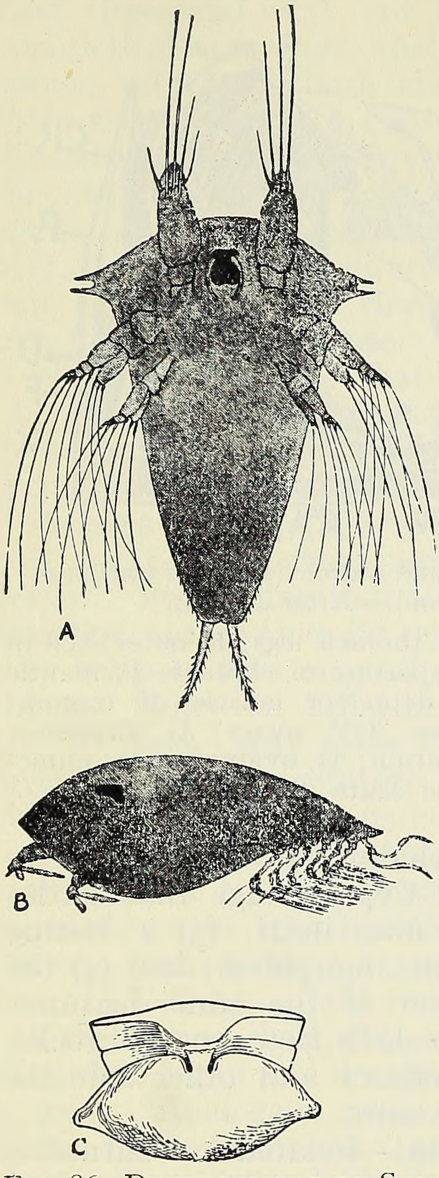


FIG. 86. DEVELOPMENT OF *Sacculina*.—After Delage. (Not drawn to scale.) A, free-swimming nauplius larva, with three pairs of appendages; B, pupa stage; C, adult protruding from the abdomen of a crab.

between male and female depends on the metabolism or chemical routine (see SEX). All the relatives of *Sacculina* and *Peltogaster* are called *Rhizocephala* (*rhiza*, root; *cephale*, head), in allusion to the root-like absorptive processes that grow from the head region. Looking backwards, we see that there are four orders of Lower Crustaceans:

Branchiopods, like Brine-shrimps and *Daphnia*.
Ostracods, like *Cypris* and *Cypridina*.
Copepods, like *Cyclops* and *Lernaea*.
Cirripeds, like Barnacles and *Sacculina*.

Higher Crustaceans or Malacostraca

(*a*) First among these may be ranked a number of relatively simple types. Noteworthy is the small shrimp-like marine *Nebalia*, which burrows in the surface layers of the sand. It differs from all the other higher crustaceans in having seven, instead of six, abdominal segments. It is a connecting-link between the Lower and the Higher Crustaceans, as may be illustrated by the fact that it has the maxillary excretory organs of the former and the antennary excretory organs of the latter.

(*b*) Also primitive, but at a higher level, is a ' mountain-shrimp ' of Tasmania, *Anaspides* by name, which is extraordinarily like one of the extinct Carboniferous fossil-crustaceans come to life again. It has many antique characters, and that is what is meant by applying to it and to similar types Darwin's phrase ' living fossil.' It frequents deep pools of rivers and streamlets, often at an elevation of four thousand feet, and never below two thousand feet. It is about two inches long, darkly coloured. Sluggish in habit, it walks about on stones and water-plants at the foot of the pool, browsing on Algae, or eating small animals. It has two relatives, old-fashioned like itself, the inch-long *Paranaspides* and the minute *Koonunga*. Our reason for noticing rare forms like these is that they illustrate so well the gradualness of evolution, and also the way in which the very distant past may live on in the present.

(*c*) Then come the delicate *Mysids* (see Fig. 91, p. 200), mostly living in the Open Sea, usually some way below the surface, but sometimes going down to great depths. There is a freshwater form, *Mysis oculata*, variety *relicta*, found in lakes in northern and central Europe, which illustrates how a member of a marine stock may become adapted to freshwater conditions. It is common in Lough Neagh in the north of Ireland. Along with the Mysids may be ranked the *Cumids* and their relatives, which are probably related to *Nebalia*.

(*d*) The order of *Isopods* is more familiar, for it includes the common wood-lice found under bark and among loose stones, and the 'sea-slaters' on the shore. Isopods are mostly flattened from above downwards; they have the same number of appendages (nineteen) as in lobsters and higher crustaceans; their eyes are never on stalks; the breathing organs are on the abdominal limbs. The number of different kinds is enormous.

Common on European and American coasts is the sea-slater (*Ligia oceanica*), which lurks in crevices just above high-water mark, but sometimes higher still if there is much spray. It is really a terrestrial animal, drowning if long immersed in water, but it requires moisture. Large numbers often lie huddled together in the dark crevices, for they avoid the light (**negative heliotropism**). At night they scatter and hunt for food, which consists of the decaying remains of plants and animals. The body is oval in shape, about an inch and a third in length, the males larger than the females, the opposite being usually true of Arthropods. The eggs are carried about in a brood-pouch, where they hatch out. The first five abdominal limbs are delicate tratelets in which the blood-vessels form an intricate network, and thus these limbs become the breathing organs. As in the wood-lice, oxygen passes into the blood through the skin of these appendages Ind carbon dioxide passes out, which is always the gist of **respiration.** In ordinary Isopods the interchange of gases is between the water and the blood; in wood-lice it is between the air and the blood; but Ligia is almost between the two, since the surface of the breathing-limbs must be kept moist.

As Ligia is one of the common animals among the shore rocks, we may note the explanation of a common puzzle, that many of the individuals that run briskly off when we disturb their retreats are distinctly lighter in colour on the hind half of their body. No doubt the colour varies considerably, from dark greyish green to light dirty brown, and is often mottled; but the puzzle is that the two ends of the body are often so very different. The explanation is that in the cuticle-moulting, or **ecdysis,** the covering of the posterior half of the body is cast first, and that the new cuticle is lighter in colour. After some days the cuticle of the front half of the body is also cast, and then, whatever the colour may be, the appearance is the same all over. We have dwelt on Ligia because it is an interesting transition among Isopods from the typically aquatic majority to the thoroughly terrestrial minority, the 'wood-lice.'

TERRESTRIAL WOOD-LICE OR 'SLATERS.'—Not very different from the seashore *Ligia* is *Ligidium*, which lives in moist places far inland. *Oniscus* is common in woods, and *Porcellio* is another of the many kinds. One that is common in gardens is called *Armadillidium*

because of its habit of rolling itself up into a living ball like an armadillo. There is a white and blind wood-louse (*Platyarthrus hoffmannseggii*), about one-tenth of an inch in length, that occurs only in ants' nests, where it is well looked after, perhaps as a reward for keeping things clean. This is a simple case of **animal partnership.** Slaters usually feed on decaying animal and vegetable matter and must be ranked among 'the cleansers of the earth,' though they may do much damage in a garden, e.g. in a strawberry bed. The respiration is different from that of Ligia inasmuch as the inner blades of the abdominal limbs are traversed by delicate tubes, a little like the tracheae of insects, which bring the air into close proximity to the blood which circulates in these delicate appendages. The female wood-louse carries her eggs in a thoracic brood-pouch until the young ones hatch out. Whereas it is usual for marine crustaceans to have young ones which are at first very different from the adult—larvae, in short—one could hardly expect this in terrestrial forms that have left the old haunts. Thus slaters have suppressed the larval stages so common among crustaceans in general. The young ones are hatched out as miniatures of the adult.

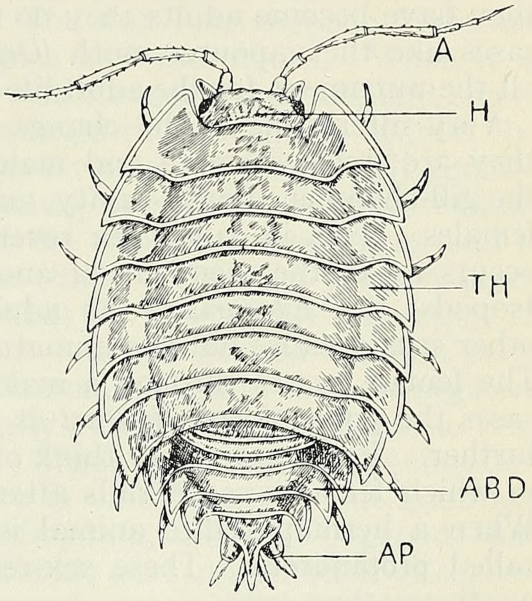


Fig. 87. Dorsal View of a Wood-louse (*Oniscus*).—After Webb and Sillem.

A, antenna; H, head; TH, segment of thorax; ABD, segment of abdomen; AP, last pair of abdominal appendages.

Not very far from the true wood-lice are the water-slaters or *Asellids*, some in fresh water and some in the sea, in which the first pair of abdominal limbs form a thin flap over the others which are entirely devoted to respiration. Very common in ditches is the freshwater slater (*Asellus aquaticus*), a sluggish, mud-inhabiting animal, about half an inch long.

From Ligia, Oniscus, and Asellus we can get a good picture of Isopods, but there are many other forms, some of them very strange. How curious are the *Tanaids* that live among the shore Algae and come out of shelter if a basin of seaweed is placed in a strong light! The males do not eat, or grow, or moult—notice the logical sequence—after they grow up. They seem to show **male dimorphism,** big males and little males, but the meaning of this is not clear. How puzzling,

again, are the *Gnathias*, common about the roots of seaweed in the Mediterranean! The larvae fasten to fishes, become distended with food, and change so much that they require a special name, *Praniza*. These larvae liberate themselves at various stages of growth, and develop into males and females, so different from one another (**sex-dimorphism** this time) that their relationship was long denied. After they have become adults they do not eat any more, but remind us of cases like the vapourer moth (*Orgyia antiqua*) among insects, where all the nutriment for the adult life is acquired by the active caterpillar.

Very interesting is the change of sex in the *Cymothoas*. At first they are free-swimming and male; then they settle down, infesting the gill-chamber, mouth-cavity, and skin of various fishes, and become females. This is called **sex reversal,** and a striking fact is that it occurs in all the members of another, not nearly related, family of Isopods, the *Epicarids*. As adults they are females, parasitic on other crustaceans; but the immature young stages are males and free. The female passes through a male phase, but it is said that in some cases the young forms *that act as fertilizing males* never grow up any further. Perhaps we may think of these Epicarids as hermaphrodites in which femaleness prevails after the parasitic mode of life sets in. When a hermaphrodite animal is first male and then female, it is called **protandrous.** These sex-relations are intricate, but they are worth puzzling over.

There are many hundreds of different kinds of Isopods, and any size over an inch is counted large. There is, however, an extraordinary giant, *Bathynomus giganteus*, found in the Gulf of Mexico and the Indian Ocean, which is a foot long and four inches broad.

ORDER AMPHIPODS: Sand-hoppers and the like.—In this order the body is compressed from side to side, the breathing organs are on the thoracic limbs, and the heart, which is posterior in Isopods, is anterior. Very representative are the sand-hoppers, so familiar on the beach, especially when we lift up the jetsam. Two common genera are *Talitrus* and *Orchestia*, which clean up decaying plants and animals on the shore. They have great powers of jumping, by a sudden bending of their body; and some of them pass readily into immobility (**animal hypnosis**). When lifted on to the palm of one's hand they remain quite immobile for a minute or two, and then with a jerk they are gone. A European species, *Orchestia gammirellus*, is sometimes found in moist gardens, many miles from the shore. The true sand-hoppers form the family *Talitridae*.

Nearly allied are the *Gammarids*, well represented by the common freshwater *Gammarus pulex*, called in Scotland the ' screw,' in reference to its wriggling sideways motion. A very unfortunate name is ' freshwater shrimp,' for the structure of Gammarus is far away from that of

shrimps. On the seashore on both sides of the Atlantic the commonest species is *Gammarus locusta*, a notable scavenger of the pools.

When Gammarus is resting, it lies curled up on one side, slightly fixed to the substratum by the tips of the last three thoracic legs. The abdominal limbs keep up a fanning movement, which wafts water to the gills on the thoracic limbs. The first four thoracic limbs are used to waft water and food particles into the mouth. When it is creeping, the ' screw ' feels its way with its long antennae, and levers itself along by pushing with its posterior thoracic limbs against the substratum. When it is swimming, however, it jerks itself rapidly by alternately bending and straightening the tail or abdomen. Gammarus is evidently uncomfortable if the water becomes warm, and it also retreats from the light into the shade. This is a good instance of a **tropism,** an obligatory movement in a particular direction in relation to some particular stimulus. As the normal reaction is to move rapidly away from the light, Gammarus is said to show **negative heliotropism** (p. 194). It automatically adjusts its movements so that it jerks away from the bright light. When there is little illumination and the same all round, the creature is ' indifferent.' But Loeb has shown for Gammarus, the water-flea *Daphnia*, and some Copepods that if a very little weak acid, like the carbonic acid in a solution of carbon dioxide (soda-water), is added to a vessel containing the animals in an indifferent state, they become for a short time positively heliotropic, and rush to the window side of the dish. In Daphnia this **reversal of tropism** lasts for ten to fifty minutes, but in Gammarus for only a few seconds. What physiological change reverses the tropism remains uncertain, but there are many instances of the change-about. The caterpillars of *Porthesia* make for the light before a meal, but they lose their heliotropism almost completely after they have eaten. Male and female winged ants show a positive heliotropism, but as soon as they lose their wings their heliotropism ceases.

The freshwater *Gammarus pulex* is an interesting animal to watch in a shallow glass dish. It has a dull greenish-yellow or brown colour. Spots of bright vermilion on the abdomen and on the basal joints of the legs indicate the position of unicellular glands. The male is larger than the female, towards four-fifths of an inch long, and he often carries his mate about with him, holding her by his anterior thoracic legs. The legs pass into a brood-pouch on the under-side of the female's thorax, and thence the young ones emerge as miniatures of their parents. A curious sort of married life!

Very quaint Amphipods are the ' no-body crabs ' or *Caprellids*, which creep about among the seaweed, with stick-insect-like attenuated bodies difficult to detect. On the skin of whales there is a related

ectoparasite, *Cyamus ceti*, whose body is flattened out laterally, not elongated as in Caprellids. Very interesting also is *Phronima sedentaria*, a transparent form that lives as a full-grown female inside a small translucent barrel of the fire-flame or *Pyrosome*, a free-swimming colonial Tunicate (see TUNICATES). The Phronima, about an inch long, kills the Pyrosome, but keeps the case as a shelter for herself and for her brood. She comes very near making a boat of the Pyrosome, for she sticks her tail out behind, and by alternate flexing and straightening it, she drives the barrel through the water. This has the further advantage that water enters the front end of the barrel as it is scooped out behind, and this brings in minute organisms which are of use to the Phronima. This should probably be called a **shelter-association.** There is a touch of romance about it!

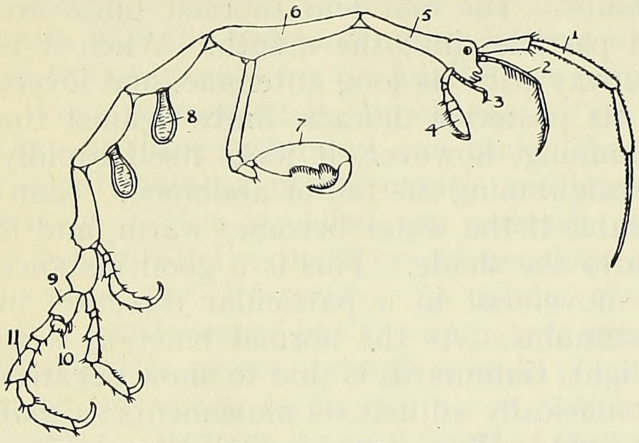


FIG. 88. A 'NO-BODY' CRAB (*Caprella*)
1, 2, antennae; 3, thoracic appendage; 4 and 7, thoracic appendages ending in claws; 5, 6, thoracic segments; 8, gills; 9, eighth thoracic segment; 10, abdomen—a tiny wart at the end of the greatly elongated thorax; 11, hind leg.

SQUILLIDS.—These quaint creatures, often six inches long, may be placed next the Amphipods, but they have stalked eyes, a carapace-shield covering the four front segments of the thorax, an exaggerated food-seizing second foot-jaw (maxillipede), and strong swimming abdominal appendages. Squillas are common in the Mediterranean, living in shallow water in holes or in the sand, and can be recognized at once by the exaggerated foot-jaws or maxillipedes, which closely resemble the front leg of the strange insect known as the 'praying mantis.' Smith and Weldon point out that the female Squilla carries 'the developing eggs in a chamber improvised by the apposition of the maxillipedes, so that it looks rather as if she were in the act of devouring her own brood.' The larval stages are extraordinary in appearance and complicated in their sequence.

When two quite unrelated animals show a striking resemblance in some structure or feature, because they are similarly adapted to similar conditions of life, the resemblance is called **convergence** or **homoplasty,** and a good instance is the likeness between the raptorial appendages in Squilla and in Mantis. They are very like one another, yet they must have arisen quite independently, since crustacean and insect are very far apart.

ORDER EUPHAUSIDS.—The highest orders of crustaceans are the *Euphausids* and the *Decapods*. In both there is a carapace-shield covering the whole of the thorax; the eyes are stalked; there is no brood-pouch, but the eggs are glued on to the abdominal limbs; and the heart is compact.

The Euphausids are very abundant, very widespread, somewhat shrimp-like animals, sometimes living near the surface, and at other times in deep water, or remaining permanently in darkness. It may be that their frequently elaborate **luminescent organs** help them to find their way about in the dark waters. In any case it seems necessary to discover some utility when the luminescent organs are not merely simple glands, but elaborate structures with a lens and a reflector as well as light-producing tissue. They often occur at the bases of the thoracic legs and on the outer margin of the stalked eyes. The light is probably produced as the result of a rapid fermentation of a luminiferous secretion, *luciferin* (see INDEX).

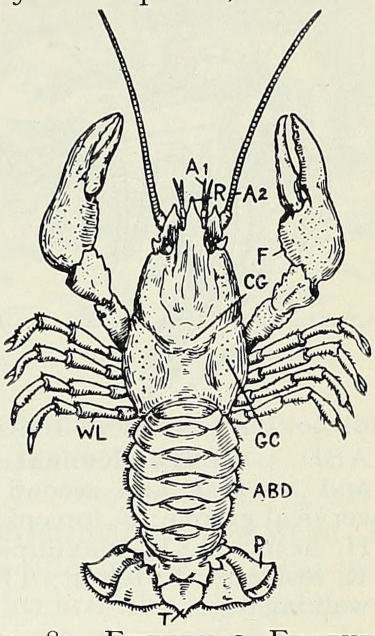


FIG. 89. EXTERNAL FEATURES OF THE EUROPEAN FRESH-WATER CRAYFISH (*Astacus fluviatilis*)

A 1, first antennae; A 2, second antennae; R, rostrum; F, forceps; CG, cervical groove; GC, gill-covers; WL, walking legs; ABD, abdomen; P, paddles; T, terminal plate or telson.

A very interesting fact in regard to the Euphausids is that the first larval stage is a nauplius as in the Lower Crustacea, whereas the first larval stage in Decapods is in most cases a more advanced form, called a *Zoaea*. This may be taken as an indication that all the crustaceans sprang from an ancestral stock with a nauplius larva. A less theoretical fact of interest is that Euphausids form an important part of the food-supply of various Open-Sea animals, such as certain fishes, including herring. In Antarctic waters the penguins capture enormous numbers and carry crops full of them to their young ones on shore.

ORDER DECAPODS.—The long series of crustaceans finds its climax in lobsters, hermit-crabs, and true crabs. They are called Decapods because there are ten conspicuous thoracic limbs, the pair of forceps and the four pairs of walking legs. When the tail or abdomen is long and held out in a line with the carapace-covered cephalothorax (fused head and breast), the term *Macrura* is used. Here are included the common lobster (*Homarus*), the decorative rock-lobster (*Palinurus*), the Norway lobster (*Nephrops*), the European freshwater crayfish

(*Astacus* or *Potamobius*), the North American freshwater crayfish (*Cambarus*), and a large number of shrimps and prawns. The common Mediterranean prawn is called *Peneus*, and has an interesting life-history. The first free stage is a Nauplius, the second a Protozoaea, the third a Zoaea, the fourth a 'Mysis,' so called because it is so like the genus Mysis which we have mentioned at a much lower level. After another moult the Mysid larva becomes a completely equipped Peneus.

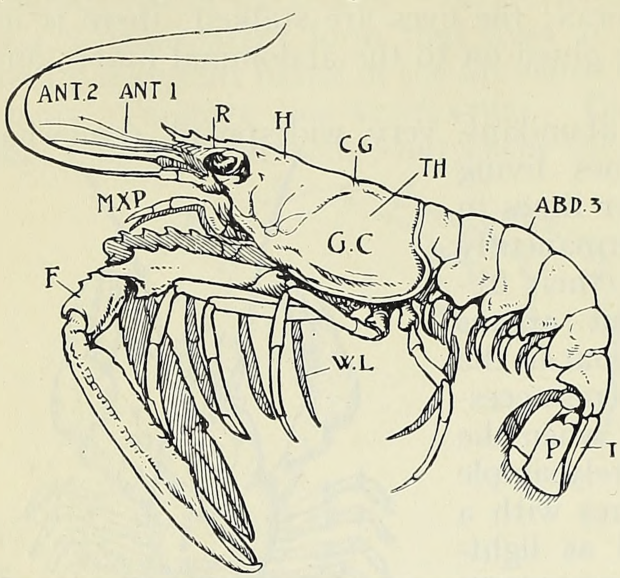


FIG. 90. THE NORWAY LOBSTER (*Nephrops*) ABD 3, third abdominal segment; ANT 1 and 2, first and second antennae; CG, cervical groove; F, forceps; GC, gill-cover; H, head; MXP, maxillipede; P, paddle; R, rostrum; T, telson; TH, thorax; WL, walking leg.

The commonest British shrimp is *Crangon vulgaris*, and the commonest British prawn is *Palaemon serratus*. How can we tell the one from the other? The shrimp has a somewhat depressed body with a rudimentary beak or rostrum between the eyes. The prawn has a more compressed body with a well-developed toothed beak. Another prawn is *Pandalus*, with two (equal) filaments to the little feelers or antennules, whereas Palaemon has three filaments. Like Pandalus, but with the two filaments very unequal in thickness, and with the first pair of legs short, not long, is the genus *Hippolyte*. The Aesop prawn (*Hippolyte varians*) is justly famous for its **colour-change**, about which a little must be said. This prawn lives near shore, and it may be green on the sea-grass, brown on the tangle, and red on red seaweed, thus assuming a cloak of invisibility. Moreover it can adjust its pattern as well as its colouring to suit its immediate surroundings. It has three pigments—red, yellow, and blue—which are contained in contractile **pigment-cells** or **chromatophores**, and the change of colour depends on

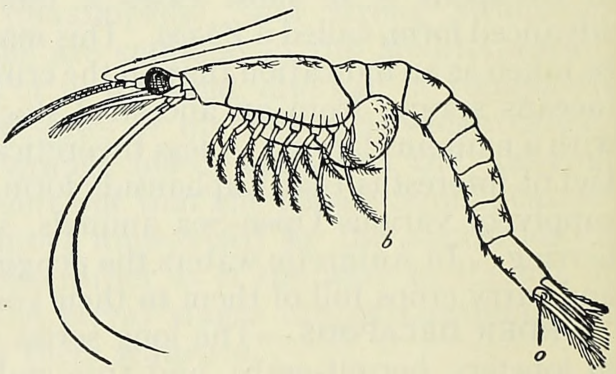


FIG. 91. *Mysis flexuosa*, FROM SIDE *b*, brood-pouch; *o*, otocyst in tail.

the prominence of some and the practical suppression of others. The larval Aesop prawns have very little pigment, only a slight whitish or greenish tint. According to the surroundings which they select, they become in a day or two of the same colour, and in variegated ways, according to the light and shade, they show a colour-pattern. The pattern cannot change, but the colouring may change if the animal shifts from one background to another, or if the intensity of illumination varies. In all cases, however, whatever be its colour, the Hippolyte changes to a transparent azure blue at nightfall. Next morning it reassumes its previous colour.

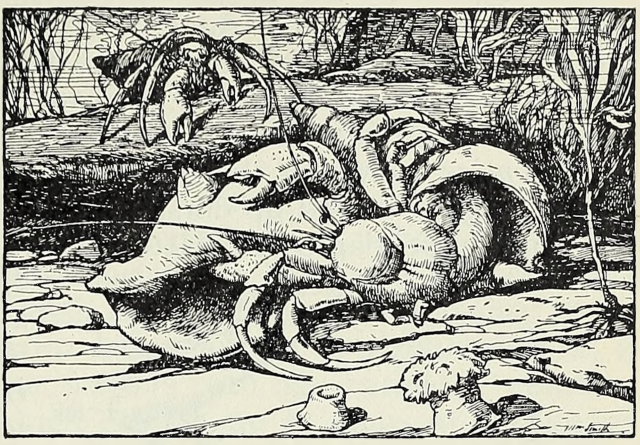


FIG. 92. HERMIT-CRABS (*Pagurus*)

The second group of Decapods, known as *Anomura*, may be described as intermediate between lobsters and crabs as regards the condition of the tail or abdomen. It is not a powerful locomotor organ as in lobsters and crayfish, shrimps and prawns. It is not greatly reduced in size as it is in crabs. Very characteristic representatives of the group are the hermit-crabs (*Pagurus*), with soft tails sheltered in a borrowed shell. Inseparable from these are the robber-crabs (*Birgus*) and the stone-crabs (*Lithodes*).

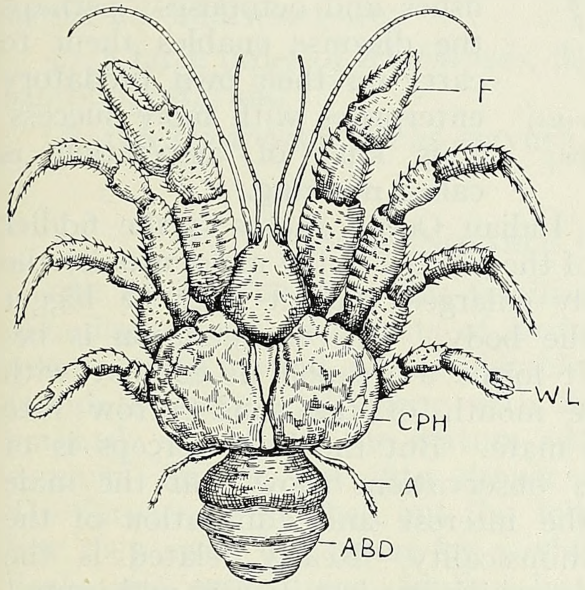


FIG. 93. ROBBER-CRAB (*Birgus latro*)
A, last thoracic appendage; ABD, abdomen; CPH, cephalothorax; F, forceps; WL, walking leg.

Less nearly related to the lop-sided hermits are the beautiful symmetrical *Galatheas*, in which the abdomen is not permanently folded up against the thorax, and the little porcelain-crabs (*Porcellana*) in which it is, so that a crab-like form results. These types point the way to the evolution of crabs. Here also are included the quaint burrowing mole-crabs, which have legs suited for burrowing into the sand. People who do not

believe in evolution should get to know the links that connect lobsters, hermit-crabs, and crabs.

The highest of all the crustaceans, with the most concentrated nervous system, are the true crabs, or **Brachyura,** which means short-tailed. Their characteristic is the reduction of the tail region or abdomen, which is completely bent up on to the ventral surface of the thorax, and cannot be seen from above. The most primitive crabs are the *Dromias*, in which the tail is least reduced, and the last pair of walking legs is turned up dorsally. In the swimming-crab (*Portunus*) the same appendages are flattened out into paddles. *Thelphusa* or *Potamon* is a good example of a freshwater crab. The long-legged spider-crabs, such as *Hyas* and *Inachus*, often plant seaweeds, sponges, and zoöphytes on their carapace and limbs, so that their real nature is disguised. Perhaps the growth conceals them from the hungry eyes of predacious fishes and octopuses; perhaps the disguise enables them to carry on their own predatory enterprises with more success. This kind of association is called **masking.**

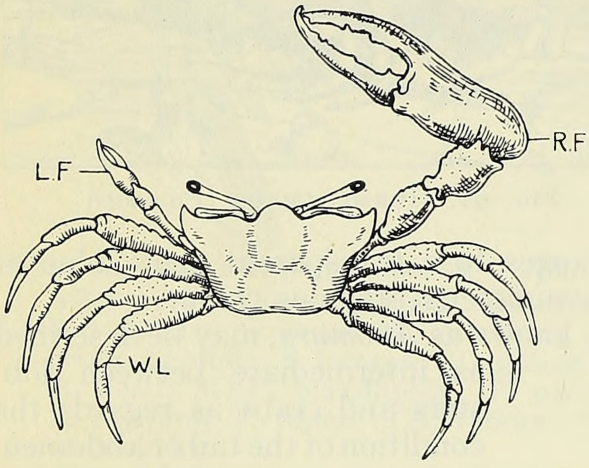


FIG. 94. A FIDDLER-CRAB (*Gelasimus*)
LF, left forceps; RF, right forceps; WL, walking leg.

A very quaint little crab on Indian Ocean shores is the fiddler (*Gelasimus annulipes*), with one of the forceps in the male, usually the one on the right, so enormously enlarged that it may be bigger than the whole of the rest of the body. This exaggeration is believed to have several uses. It forms a weapon in combat with rival males. It may stop the mouth of the sand-burrow into which the male retires with his mate. But the huge forceps is of a vivid red colour, and Alcocks' observations show that the male brandishes it about to excite the interest and admiration of the females, who have no such whimsicality. Nearly related is the quickly moving land-crab *Ocypoda*, which has lost its gills and cannot live in the water. The internal walls of what should be the gill-chambers have tufts rich in blood-vessels, and by means of these the Ocypod is able to breathe dry air. Another land-crab, *Gecarcinus* of the West Indies and West Africa, often lives several miles from the shore, and affords a good instance of true **migration.** That is to say, there is a seasonal mass-movement between a breeding-place and another habitat. In spring there is a rush of full-grown crabs from

the interior to the shore, where they pair and spawn, and whence, after a while, they migrate back again to their everyday life. For a short part of the year they are concerned with reproduction, for most of the year with nutrition. Thus there is an annual see-saw between love and hunger. The young crabs, hatched out in the salt water, pass through their larval stages off shore, after the manner of their race. Long after their parents have left the shore there is an inland journey of miniature crabs.

Not very distantly related to the land-crabs (*Gecarcinus* and others) are the little pea-crabs, whose rounded shape is indicated by their name. They illustrate **shelter-associations:** thus the species called *Pinnotheres pisum* lives off British coasts in the mantle-cavity of the Norway cockle. Another quaint habit is seen in *Aratus pisonii*, in the related family of *Grapsidae*, for this crab has learned to climb up on the mangroves, and gets high enough up to gnaw at the leaves. Everywhere we come across these instances of the **insurgence of life.**

Looking backwards over the Higher Crustaceans, we recognize:

(*a*) several primitive old-fashioned types, such as *Anaspides* and *Nebalia*;

(*b*) a large order of *Isopods*, flattened from above downwards, such as sea-lice and wood-lice;

(*c*) a large order of *Amphipods*, flattened from side to side, such as sand-hoppers; and

(*d*) the *Decapods*, such as crayfish, hermit-crabs, and true crabs.

Some Notable Crustaceans

THE EDIBLE CRAB.—This familiar crustacean, *Cancer pagurus*, is abundant round the coasts of Britain and other countries. It frequents rocky ground, at considerable depths; but young ones are often found in shore pools along with those of the shore-crab (*Carcinus maenas*). In winter the mature adults—over five inches in breadth—move further out into deeper water, where spawning occurs. The larvae are hatched out the following spring in inshore waters, but they swim out again for a while into the more open stretches. Crabs are carnivorous, feeding largely on dead fishes. Nevertheless, as every one knows, they are very palatable. Except for bait it is illegal to sell crabs under four inches across, or when they are carrying eggs (' in berry '), or when they have just moulted (' soft ').

An inspection of an edible crab shows a substantial *carapace*, the cephalothorax shield, which encloses the head (cephalothorax) region and the breast (thorax) region, not only above and at the sides, but below. Moreover the margin of the shield is continued outwards and

downwards as a hollow flap enclosing the gill-chamber, within which there lie nine gills on each side, feathery outgrowths of the side-walls of the thorax. The water enters by two small inhalant apertures, being sucked in by the wafting action of the ' baler,' which is part of the second pair of maxillae.

The third region of the body—the abdomen—is much reduced in crabs, and is tucked under the ventral surface of the cephalothorax, between the bases of the walking legs. It is narrow in the male, and broad in the female—the breadth being an adaptation to the fact that she carries her eggs under its shelter. The strange parasite *Sacculina* (p. 191) is occasionally found protruding like a big bean between the abdomen and the cephalothorax. It should be noted that in the early stages of the crab's life-history the abdomen projects backwards in a line with the thorax, as it does permanently in the less specialized lobsters and prawns. This may be taken as an example of **recapitulation,** the individual's repetition of the racial evolution. Another fact of general interest is that a careful scrutiny of the crab's body in the course of its development shows the usual architecture of higher crustaceans — five segments to the head, eight to the thorax, six to the abdomen—nineteen in all.

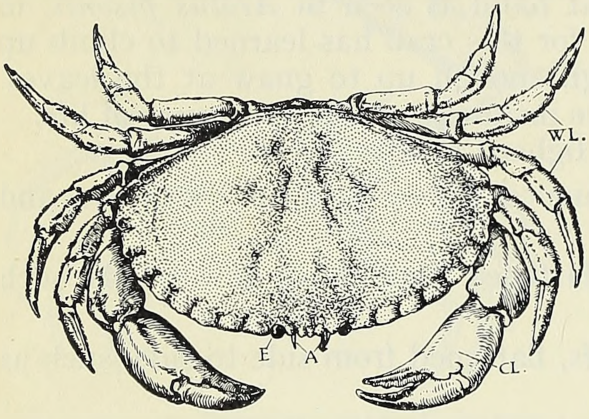


FIG. 95. THE EDIBLE CRAB (*Cancer pagurus*), DORSAL VIEW
A, antennae; CL, claw or chela; E, eye; WL, walking legs.

The antennules or first pair of feelers lie in deep depressions on the anterior margin of the carapace. Two small hair-like whips arise from the tip of a folded basal piece, and the outer whip is sensitive to odours. The antennae or second pair of feelers are a little further to the side, each showing a strong, straight tactile whip. A little further outwards are the stalked eyes. Beside the mouth are the strong jaws or mandibles, two pairs of maxillae, and three pairs of foot-jaws or maxillipedes, the third pair covering the others as if with a strong folding door on each side. On the living crab it is interesting to detect the movement of the ' baler,' that keeps the water moving from behind forwards over the well-hidden gills.

Then follow the great fighting claws or chelae, and the four pairs of walking legs. On the abdomen of the male there are two pairs of appendages which are modified for transferring the sperm-cells on to the eggs of the female. On the female's abdomen there are four pairs

of appendages, and on to some of their bristles or setae the liberated eggs are glued. There they are fertilized and there they develop and are hatched.

Most male crabs above four inches long are mature. That is to say, they produce male elements or spermatozoa at the breeding season, which is in winter. The male elements are in little packets or capsules called **spermatophores,** and these are transferred by the male to the oviducts of the female, which open on the under-surface of the thorax near the base of the second pair of ordinary walking legs. The spermatozoa of the crab, like those of most crustaceans, are non-motile, whereas those of most animals are adapted for active movement, and are able to move in water or inside the oviduct for considerable distances by means of a microscopic lash or flagellum. Thus ordinary spermatozoa are able to find the ova without being liberated close beside them. As this is not the case in the crab, it is not surprising to find that the spermatozoa pass into the oviduct of the female, illustrating **internal fertilization,** as in all backboned animals from Reptiles to Mammals inclusive. The spermatozoa are stored in the female crab, in a special reservoir (*spermatheca*) connected with each oviduct, and they remain there for many months before they fertilize the eggs. The openings of the oviducts are plugged by a secretion.

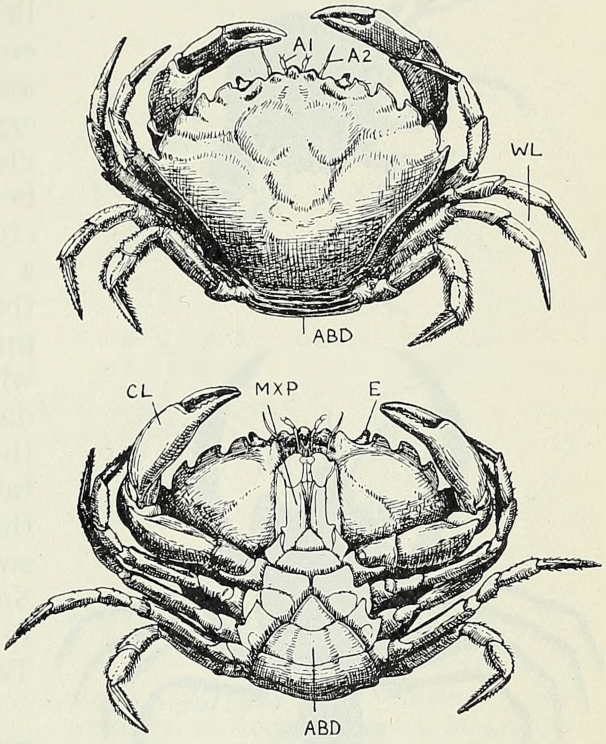


FIG. 96. THE SHORE-CRAB (*Carcinus maenas*), DORSAL (above) AND VENTRAL (below) ASPECTS

A 1, antennules; A 2, antennae; WL, walking leg; ABD, abdomen; CL, claw; MXP, third maxillipede; E, eyes.

The ripe eggs inside the female crab have an orange-red colour, due to a pigment (*zoönerythrin*) in their yolk. Immediately after a moult, while the female is still ' soft,' there is sexual union between the male and the female, and the transference of sperms (**insemination**) occurs. Many months afterwards, in the winter, the eggs are liberated, that is to say, **spawning** takes place. But it is at the time of spawning that **fertilization** is effected, that is to say, an intimate and microscopic

union between the egg-cell and the sperm-cell. It is important for clearness to distinguish between insemination and fertilization.

When the multitudinous eggs of the female crab are liberated, they adhere to the bristles of the inner forks (*endopodites*) of the abdominal appendages. How is this effected? It seems that a bristle or seta pierces the outer envelope of an egg and liberates an adhesive fluid, so that the eggs are skewered as well as glued to the bristles. It has been computed that a small ripe crab 'in berry' may carry half a million eggs, and a large one three millions. This prolific multiplication makes one ask why crabs are not more abundant, and the answer is that there is enormous 'infantile mortality.' A large percentage of the free-swimming larvae are swallowed by larger animals. *So careful of the type she seems; so careless of the single life,* as Tennyson said.



FIG. 97. LARVAL STAGES IN THE LIFE-HISTORY OF THE CRAB

Above: the Zoaea with maxillipedes (MX), spine (SP), and abdomen (AB).

Below: the Megalopa, with antennae (AN), walking legs (WL), and abdomen (AB).

The eggs go on developing under the shelter of the mother's tail, and the development is very slow. It lasts for about seven months, and the mother crab seems to depend on its previously stored resources for most of this period. In the summer months the liberation of the larvae is effected, and this is helped by the mother moving her tail backwards and forwards, and also brushing a little with the last pair of walking legs. The larvae swim off and there is a succession of stages—called *Protozoaea*, *Zoaea*, and *Megalopa*. The Zoaea stages, which are separated from one another by moults, are marked by long spines projecting from the back and the middle of the back. These are lost in the Megalopa stage, which is beginning to look more like a crab. The tail sticks out in a line with the head-and-breast; in other words, it is in

the position seen in the lobster. This is part of the individual crab's **recapitulation** of its racial history, for there can be no doubt that crabs, with their tucked-up tails, were evolved from crustaceans of the shrimp and lobster type. At the end of the Megalopa stage, which is a short one, there is another moult, and the young creature is at last a miniature crab. It is no longer a swimmer in the open waters; it creeps about on the floor of the sea, using its four pairs of walking legs.

Looking back over this interesting life-history of a very common animal, we may notice that the pairing is in autumn, the spawning in winter, and the liberation of the larvae in summer. After that comes the long-drawn-out succession of free-swimming larval stages, many of which do not survive to become miniature crabs.

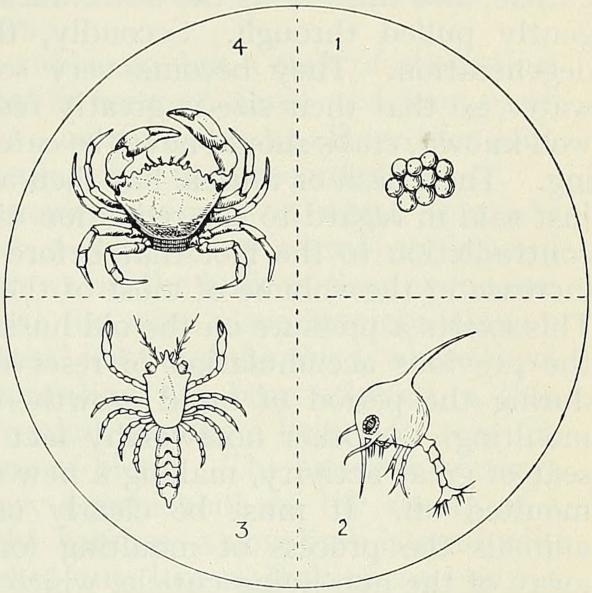


FIG. 98. LIFE-HISTORY OF COMMON SHORE-CRAB (*Carcinus*)

1, spherical eggs with chitinous envelopes; 2, Zoaea larva; 3, Megalopa larva; 4, adult crab.

MOULTING.—The process of cuticle-casting has been very carefully studied in the crab, and what is said here will apply to other cases. On the seashore one sometimes finds a dead crab from which bacteria have cleaned away all the flesh. Oftener, however, especially in the case of the shore-crab (*Carcinus maenas*), one finds a relinquished 'moult,' and it can be recognized at once because the top comes off when it is lifted. There is a neatly cut line, which indicates how the dead shell divided and let the living tenant out. This longitudinal line is clearly marked in a living crab, and will be seen running along each side of the cephalothorax shield. It is connected at moulting time with a transverse line of rupture that runs across dorsally between the posterior margin of the carapace and the front of the first segment of the tail. When the top half of the moult is lifted off, one sees that the crab has left behind it its tendons and the outer pellicle of its gills. This shows how thoroughgoing the moulting is.

When the crab, which has grown too big for its shell, begins to moult, it gets the tail clear first. Then it gets its muscles out of the covering of the legs. Finally it pulls itself free from the anterior skeleton, which has broken along the prearranged line of weakness

already mentioned. In the lobster type, the thorax is freed first and the tail last.

It is difficult to understand how a crab or any similar crustacean can get its muscles through the narrow joints of the legs. Part of the answer is seen in the case of the great claw or chela, for along faint lines towards the base there is an absorption of the limestone in the cuticle, and this allows the outer husk to yield when the big muscle is gently pulled through. Secondly, the muscles undergo a kind of degeneration. They become very soft, and finally they lose much water, so that their size is greatly reduced for the time being. As is well known, crabs should never be eaten just before or just after moulting. Their flesh or muscle has then a bitterish taste. What we have just said in regard to the reduction of the size of the muscle is not in contradiction to the fact that before the moulting there is a general increase in the volume of most of the tissues, as well as of the blood. This exerts a pressure on the old husk. This is partly connected with the previous accumulation of reserve materials which will be useful during the period of rapid growth—without food—that follows the moulting. Another noteworthy fact is that the exposed skin is the seat of great activity, making a new cuticle to replace what has been moulted off. It must be clearly understood that in backboneless animals the process of moulting (or **ecdysis**) is always a throwing away of the non-living cuticle, which is formed by the dying away of the outermost parts of the cells of the living skin. It would be death to any animal to cast its true skin or epidermis. As a matter of fact, before the old husk has been got rid of, the epidermis has prepared a new one, and there is some gelatinous fluid between the two. During the time of moulting the crab keeps quiet, but the female crab is inseminated before her new shell has hardened.

The fishermen in some places give the name *'granny' crab* to females that they find in late summer and early autumn, marked by dirty shells and broken claws. Their flesh has a bitter taste and a purgative effect. The fishermen usually regard these 'grannies' as diseased, and kill them accordingly. But Dr. Joseph Pearson has shown that this is an unfortunate mistake, and that 'grannies' are merely crabs that are ready for casting the cuticle. They are found only among the biggish crabs, above six inches across, and they are almost always females. It seems that male crabs above six inches moult more frequently than the females of similar size, and that the females are more severely affected by the process. Males of over six inches appear to moult once in two years, but the females less frequently, probably once in three years.

Moultings are most frequent when crabs are young, for the simple reason that the rate of growth is much greater. During the first year

of its life the edible crab may cast eight times; in the second and third years twice annually; in the fourth and fifth years once annually. After that the males moult every second year, and the females every third. All of these are general statements, for the number of moultings depends on the rate of growth, and this depends on nutrition and other conditions of life. Very large crabs are sometimes captured carrying growths of epizoic animals, such as acorn-shells, which look as if they have lived there for over three years.

It is very difficult to estimate a crab's age, but a crab of about four inches across the carapace is probably between three and four years old; and a ratio of increase of about a quarter may be allowed for each successive year. An age of twelve years has been recorded.

AUTOTOMY.—The crab is a convenient animal on which to study self-mutilation or autotomy. When a walking leg is seriously injured towards the outer end, the crab throws off the bulk of the appendage, and the amputation always occurs at the same place, namely, along a *fracture-plane* between the second basal joint and the third, where there is a thin groove. When the amputation has been effected, a thin membrane or bandage covers the wound, leaving a little gap near the middle which is closed by a clotting of blood. The bandage becomes black for a while, and is often very conspicuous on the stump of a crab's leg. Under the shelter of the bandage a new limb is gradually formed in miniature, and this is shot out, like a Jack-in-the-box, at the next moult. There could hardly be anything neater than this amputation and bandaging and mending!

There is no doubt that arrangements are made beforehand for the possibility of self-amputation or autotomy (*auto*, self; *tomia*, cutting). For not only is there a breakage-plane or line of weakness, where the limb is surrendered—there is also a double membrane or diaphragm stretching across internally, leaving only a small opening for the nerve and the blood-vessels of the limb. This bandaging membrane prevents bleeding to death; the small opening is readily closed with a clot; the bandage forms a protection, underneath which there is great activity of cells, resulting in the **regeneration** of a new limb from the stump. It is a striking fact that the cells of the stump should be able to build up a fit and proper limb. It looks as if they retained hereditary characters in reserve; we do not know what else to say.

What is the nature of the amputation? It is what is called a **reflex action,** which does not require the activity of the brain. The serious injury to the limb sends a message along the limb-nerve, and this passes to the nerve-centre or ganglion of the segment to which the limb belongs. From the centre there issue other nerve-impulses which travel outwards to the base of the limb and lead to an extreme contraction of muscles. These muscles work against one another, and break

the leg at the weak plane. In the edible crab the stimulus to the breaking reflex is a serious injury to the leg; but in some other crabs (spider-crabs and *Grapsids*) *danger* is said to be sufficient stimulus. They may, for example, throw off a leg in order to escape from an enemy. Perhaps this is what is called a conditioned reflex (see ANIMAL BEHAVIOUR).

Dr. Joseph Pearson has explained some of the conditions of self-amputation. (1) The crab must be in full vigour. (2) Everything depends on a sufficient stimulation or excitement of the particular nerve of the limb. (3) There must be no injury to the appropriate nerve-centre in the ventral nerve-cord. (4) An upward movement of the fused second-and-third basal joint is necessary if the amputation is to be effected; and the appropriate muscles must be intact. (5) The outer portion of the leg must come in contact with some point of resistance, for this tends to prevent the upward movement of the basal part already referred to. A great strain is thus produced on the basal part, and it snaps across the weakest line, which is the breakage-plane. (6) The injury must occur between the breakage-plane and the second outermost joint of the leg. The nerve is not continued into the outermost joint, and injury below the breakage-plane is not followed by autotomy.

In the little Amphipod called *Gammarus* (p. 196), allied to sand-hoppers, an injured leg is nibbled down to its base—a quaintly primitive kind of surgery. If a prawn's leg be violently seized, the animal gives a vigorous jerk with its tail, and the leg usually breaks off at the base between the second and third joint. But if the breakage fails, the prawn may be seen to tug at the limb with its jaws. Similarly, though a hermit-crab sometimes shows an amputation just as direct and perfect as the crab's, it sometimes plucks at an injured limb with its forceps, or may even bite it down to the breakage-plane. These instances of nibbling are very interesting, for they suggest instinctive behaviour rather than reflex action (see ANIMAL BEHAVIOUR). Perhaps they suggest a dim intelligence.

In the edible crab and in the shore-crab the amputation cannot be effected unless the outer part of the leg is pressed against something hard, such as a stone, or it may be a part of the animal's own shell. But it is reported that in the sand-crab (*Hyas areneus*) and in the swimming-crab (*Portunus*) it is not necessary to have any *point d'appui*.

Long jointed legs with great freedom of movement, as engineers would say, are important acquisitions, but there is a tax to pay, and that is the risk of breakage. A common accident on the seashore is that a dislodged stone pins down a lanky limb. The animal escapes by autotomy. Or the injury may be so serious that fatal haemorrhage would soon occur unless prompt measures are taken. Or it may be that the crustacean leaves a limb in its enemy's grasp and escapes

with its life. There is also considerable risk of a limb being damaged in the intricate process of moulting. To meet these risks there has gradually evolved a very perfect response—*autotomy followed by regeneration*. Somehow or other, the animal has come to learn, in its body if not in its brain, that it is better that one member should perish than that the whole life should be lost.

But when we use a phrase like ' a limb for a life ' we are apt to think of a *reflective* creature, whereas almost all the facts go to show that the amputation is nowadays quite *reflex*, just like our coughing-up of a crumb that threatened ' to go down the wrong way.' But although the crab does not require its brain nowadays when it is amputating its limb, it is quite possible that it acted with some awareness and with some shrewdness during the long ages that must have been necessary for the establishment of such a very perfect reflex.

We may go further and ask whether there are not cases nowadays where the mental factor is still operative. Thus Piéron tied a *Grapsus* crab to a peg within view of a sheltered crevice in the rocks. The crab discarded the imprisoned limb, and Piéron thought that it did so because it saw the inviting shelter. And he came to that conclusion because the crab did not surrender its limb when its brain was put out of gear. This suggests that the brain was decisive. But the same experiment with the same kind of crab was made by Mlle Drzewina, and she was not able to corroborate Piéron's conclusion. In the ordinary crabs the process is certainly reflex, not reflective—nowadays, at least.

In the case of the fiddler-crab (*Gelasimus tangeri*), man makes a quaint use of the animal's autotomy. In that crab, as already mentioned, one of the male's great claws is as large as the rest of the body. So it is obviously the most valuable part, as far as man's appetite is concerned. In the south of Spain the fishermen cut off these great claws at the breakage-plane, and send them to market, replacing the maimed crabs in the sea to grow new ones for another occasion!

Following the method of this book, we may for convenience bring together a few other cases of **autotomy** followed by **regeneration**:

Most lizards surrender their tails.
Many male cuttlefish surrender an ' arm.'
Many worms give off large pieces of their body.
A starfish relinquishes an ' arm.'

Sometimes there is autotomy without subsequent regeneration, as in some long-legged insects.

THE CRAYFISH AND ITS RELATIVES.—The freshwater crayfish (*Astacus* or *Potamobius fluviatilis*) (see Fig. 89) is common in many rivers of Europe, and is well known in the Thames and the Isis. It

occurs in Ireland, but not in Scotland. It has a counterpart in North America called *Cambarus*.

The crayfish, whose name is derived from the old French *crevice*,[1] is like a miniature lobster, and is rarely over four inches long. But this is gigantic for a freshwater Invertebrate. There can be no doubt that it is a derivative of a marine stock, that learned to colonize the fresh waters. Similarly, there are freshwater crabs, a freshwater *Mysis*, freshwater *Gammarids*, freshwater *Isopods*, and so on. When we find within a class an enormous majority marine, and a small minority in fresh water, we are almost always safe in concluding that the original haunt was the sea. We have noticed this in studying freshwater sponges and freshwater polyps.

The freshwater crayfish is usually greenish or brownish, but it is sometimes diversified with yellow and red. Its colouring matter is the same as that of the lobsters, which we shall discuss afterwards, but it may be noted just now that it is called *zoönerythrin* (*zoön*, animal; *erythros*, red), and that is chemically almost the same as the carotin of carrots.

The crayfish is one of the light-avoiding animals, hiding by day and hunting by night. Yet, like many other animals that are shy of daylight, it is drawn to a glare, such as the river fishermen sometimes expose from their boat (see TROPISM).

The crayfish makes long burrows in the banks of streams, and, like its enemy the water-vole, it sometimes contributes to little landslips and the washing away of good soil. It has an advantage over many animals in having a long bill of fare, for in the struggle for existence it is always useful to be able to turn from one kind of food to another as the supply changes. The crayfish will eat worms, insect larvae, water-snails, tadpoles, young water-voles, the roots of aquatic plants, and the stonewort *Chara*. It often lies expectantly in wait at the mouth of its burrow, and it is said to venture occasionally on shore in search of vegetable food. It eats the moulted cuticles of its neighbours, probably for the sake of the calcium salts. It will also resort to cannibalism, and will sometimes devour its mates. But this was almost certainly observed in conditions of captivity, which are apt to be unnatural.

There is no doubt, however, that crayfishes are almost omnivorous. They keep very quiet in winter, when food is scarce, but they do not fall into a torpid state. When they become active again in spring, usually about March, they are in poor condition. It is then, however, that the females are seen to be laden with eggs, one to two hundred being glued on to the swimmerets below the tail. These

[1] And this is ultimately derived from the same word as 'crab,' viz. *krabben*, to claw.

eggs are hatched in May or June, and the young ones spend the first few days of their life under the shelter of their mother, holding on to the empty egg-cases.

It is after an autumn moult that the male crayfish seeks out a female, and, turning her upside down, liberates the fertilizing seminal matter on her abdomen, where it adheres as a whitish mass. It consists of viscid threads enclosing innumerable, microscopic, non-motile spermatozoa. After this encounter with her mate, the female crayfish retires to her burrow, and there she liberates her eggs, which are attached by glutinous threads to the bristles of the paddle-like swimmerets. How the spermatozoa come into actual union with the ova seems to be still uncertain; but if this does not happen there cannot be any development. There is an obvious advantage in the attachment of the eggs to the mother's swimmerets, for these are in frequent movement, backwards and forwards. This helps to aërate the eggs, and to wash off impurities. But the development is very slow, lasting all through the winter; and it is not till spring that the egg-shells are burst and there emerge little transparent young crayfishes, practically miniatures of their parents.

In his *Crayfish: an Introduction to Zoology* (1880) Huxley quotes a passage from an old naturalist, Roesel von Rosenhof, who watched the development of the crayfish about the middle of the eighteenth century. 'When the mother of these little crayfish, after they have begun to be active, is quiet for a while, they leave her and creep about, a short way off. But, if they spy the least sign of danger, or if there is any unusual movement in the water, it seems as if the mother recalled them by a signal; for they all at once swiftly return under her tail, and gather into a cluster, and the mother hies to a place of safety with them, as quickly as she can. A few days later, however, they gradually forsake her.' This is a good instance of very simple maternal care at what may be called a low level of life.

The liberated eggs are glued to the swimmerets by a viscid substance which hardens. When the shell splits into two, like a pair of watch-glasses, the chelae of the liberated young crayfish close on the egg-glue which is smeared over the swimmerets, or on to the halves of the emptied egg-shell. The grip is very firm, and getting free probably requires a moult. Although Roesel said that the young ones are quite like their parents, Huxley pointed out that the tips of the chelae and the walking legs are incurved, that the first and the last abdominal limbs are wanting, and that there are other slight differences.

What makes the life-history of the freshwater crayfish very different from that of the crab is the telescoping or suppression of the larval stages. What comes out of the egg is practically a miniature crayfish, for the differences already mentioned, such as the incurving of the tips

of the great claws and walking legs, cannot be regarded as very important. This **abbreviation of life-history** is common among freshwater animals, and part of its meaning must be that larval stages would be apt to be swept away by the stream. Among animals there is a deeply rooted tendency to alter the relative lengths of the arcs on the life-curve; and the tendency among freshwater animals is to lengthen out the embryonic period (before hatching) and to shorten the larval period. Variations in this direction would survive.

It is true that there are numerous insect-larvae in fresh water, and there are other instances apart from insects; but it will be found that most of these freshwater larvae have some sort of grappling organs or other structures which save them from being washed away.

GENERAL STRUCTURE AND FUNCTIONS OF THE CRAYFISH.—It is part of the method of this book to illustrate different aspects of the science in connection with different types and classes; and we shall say more than usual here in regard to structure and functions.

The crayfish has the same appendages as a lobster—nineteen pairs in all:

(1) The little feelers, or *antennules*, with a balancing ear at the base, and with peculiar smelling bristles on the outer fork.

(2) The great feelers, or *antennae*, touch-organs, with a kidney opening at the base.

(3) The strong crunching *mandibles*, like teeth, each with a little tooth-brush or palp.

(4) The first pair of *maxillae*, small and unimportant.

(5) The second pair of *maxillae*, part of which forms a ' baler ' for scooping out the water in front of the gill-chamber, so that a current is kept up.

These five pairs are borne by the head region, which is fused to the thorax region, and is covered by the conjoint cephalothorax shield. It is interesting to look at the dorsal surface of this shield to see a line like a bent horseshoe which represents the boundary between head and breast (' cephale ' and ' thorax '), for it must be understood that the fusion occurs in the course of individual development.

The thorax carries three pairs of foot-jaws or *maxillipedes* in the service of the mouth, and the third of these deserves to be looked at for the neatly toothed saw carried by the inner blade. Then come the great claws, *chelae*, or forceps, of use in seizing booty and in combat. There follow the four pairs of walking legs, the first two with claws, the last two without. The male opening is at the base of the last pair of walking legs; the female opening on the third from the last. This completes the equipment of the thorax.

The first abdominal or tail segment (No. 14) carries in the male a

pair of hard appendages, each deeply grooved, which are used in transferring the sperms into the female. The corresponding appendages in the female are small and variable. Then follow four pairs of two-bladed swimmerets, which help a little in gentle swimming, but are also used in the female for carrying the eggs. The chief swimming organs are the great paddles (No. 19), which spread out when the tail is flexed, but fold neatly inwards when the tail is straightened for the next stroke. It is interesting to notice a little toothed hinge in the outer blade, which assists in the friction-reducing ' feathering ' of the tail. As the movement that drives the crayfish through the water is a rapid jerk of the tail downwards and forwards, displacing a volume of water in the direction of the mouth, it follows that the animal swims tail foremost. But when the animal is creeping on its walking legs it progresses head foremost. All the movements are effected by highly developed, quickly contracting striped muscles; and the largest piece of palatable flesh (i.e. muscle) in the crayfish consists of the large ventral flexors or benders and the smaller dorsal extensors or straighteners of the tail.

We see then that the crayfish has nineteen pairs of appendages. These arise in the same way in the embryo as little paired buds, and they are built on the same fundamental plan, with a basal piece (or *protopodite*) carrying two blades (an inner *endopodite* and an outer *exopodite*). When structures resemble one another in their mode of development and in their fundamental architecture, they are said to be **homologous** (see INDEX), whether they occur in the same animal or in related animals. Thus the crayfish, like its relatives, is a very good illustration of **serial homology.** Yet there is great diversity of use or function among these nineteen pairs of homologous appendages. Thus the mandibles are very different in function from the paddles, and the forceps from the swimmerets. That, as we have noticed before (see INDEX), is technically expressed by saying that the appendages are not all **analogous,** though they are all homologous. Analogy is resemblance in function, and two structures may be both analogous and homologous, as in the case of walking legs, or as in the case of a bird's wing and a bat's wing, both being fore-limbs and both being organs of flight. It is useful to revise this kind of distinction, which makes for clear thinking.

An interesting point is that when a lobster loses a stalked eye it sometimes replaces this by a feeler. This shows us that the regrowth or **regeneration** is not always perfect. Perhaps it also suggests that the stalk of the eye is of the nature of a limb or appendage.

As the crayfish is a very convenient animal for practical study, we may say a little about its internal organs. The mouth is at a considerable distance from the front end, and is guarded by six pairs of

modified limbs. It leads into a large gizzard, lined with chitin and containing three large teeth, which crash against one another and break down the food. Behind the grinding region there is a sieve of bristles which prevents the food from passing on too quickly. All this gizzard, which should never be called the stomach, corresponds to the front of our mouth. Technically, it is a **fore-gut** (or *stomodaeum*), and as it arises in development as an intucking of the outer integument, it is lined with chitin. The disadvantage of this is that the whole lining, including the teeth, must be sacrificed when a moult occurs. In the late summer, before moulting begins, there is an accumulation of limestone on each side of the gizzard in the form of disk-like structures called ' crab's eyes ' or gastroliths. These consist of carbonate and phosphate of calcium, and some organic matter, and a section shows that the material is accumulated in layers. They are dissolved before the casting of the cuticle and their calcium salts are reabsorbed, doubtless making a contribution to the new shell.

Behind the gizzard there is a short digestive region (the **mid-gut** or *mesenteron*), the shortness being compensated for by the outgrowth of numerous blind tubes which form a food-digesting and food-absorbing gland. In function it is something like a stomach, a sweetbread, and a liver all combined, and thus receives the technical name of ' hepato-pancreas.' The undigested residue of the food is carried away by a long straight **hind-gut** (or *proctodaeum*) which ends on the under-surface of the telson—the unpaired piece between the great paddles.

The nervous system of the crayfish illustrates the **annulate type,** consisting of a dorsal brain, a ventral chain of ganglia, and a nerve-ring round the gullet connecting the two. Here one may learn an interesting lesson from the development of the animal. For it is found that the dorsal brain consists of two fused pairs of nerve-centres or ganglia, that the first ganglionic mass on the ventral chain (the sub-oesophageal centre) consists of six fused pairs, and that there are eleven more ganglia on the ventral chain. The addition of these makes nineteen pairs of ganglia; and thus we see that there is a pair of ganglia for each segment of the body.

An experiment made by Huxley is useful in helping us to understand what is meant by a brain. The word is convenient to denote the chief ganglionic mass in an animal's body, but this is too vague. A ganglion or collection of nerve-cells often receives tidings from the outside world, that is to say, it has a *sensory* function. But it also sends out impulses which command the muscles to move; in other words, it has a *motor* function. Thus it may be said that the brain is the chief sensory and motor centre in the body. But Huxley's experiment takes us further. When a cray-

fish is laid on its back, it is usually successful in righting itself after a number of efforts. What is required is some effective sequence of movements. But if a crayfish has been injured so that the connection between the brain and the ventral chain is broken, as wires in an electric circuit might be broken, then it cannot right itself when placed on its back. It can bite with its forceps, and chew with its jaws, and strike with its paddles, and yet it cannot get on to its feet. The reason is that the brain is required to bring about the effective sequence of movements, and this is called **co-ordination.** So the brain is not only the chief sensory and motor centre, it is the main co-ordinating centre.

The crayfish has many tactile bristles or setae at strategic places on the surface of its body. These receive nerve-fibres from a network (or *plexus*) of nerve-cells which lies beneath the epidermis. There are also taste-bristles on the upper lip of the mouth, and there are finely poised bristles inside the ear, which is a balancing rather than a hearing organ.

On the outer fork of the little feelers there are peculiarly shaped setae which are sensitive to smell. How is this known? When a crayfish is confronted with certain kinds of smelling-salts it retreats, which indicates a sense of smell. Then by a process of exclusion, removing or covering one appendage after another, it was found possible to track the sense to the antennules, and to their outer fork.

Then there are the crayfish's conspicuous eyes, differing from ours in being lidless, stalked, compound, forming an erect image, developed from the skin and not as an outgrowth from the brain. By 'compound' is meant that the eye is built up of many hundreds of lenses and other parts, whereas the Vertebrate eye has but one lens. Moreover, the image that is formed on the retina region of our eye is an inverted image—as photographing the back of the eye proves—whereas the image formed of many separate contributions in the eye of the crayfish is an erect image of the object seen. It seems that the compound type of eye is much more effective for detecting movements of objects than for imaging their precise shapes.

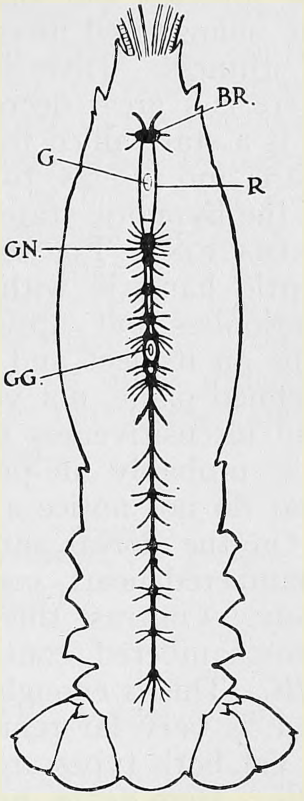


FIG. 99. CENTRAL NERVOUS SYSTEM OF CRAYFISH (*Astacus*)

BR, 'brain' or cerebral ganglia; G, oesophagus passing through nerve-ring; GG, sternal artery passing through nerve-ring; GN, sub-oesophageal nerve-ganglia; R, circum-oesophageal nerve-ring.

The crayfish can be made to illustrate an interesting state called **animal hypnosis** (cf. p. 196). When a crayfish is held on the table head downwards with its forceps broadened out to make a kind of base of support, it soon ceases to struggle. The brain sends commands to the muscles, but these are prevented by our fingers from moving; the unanswered messages cease; and the creature passes into a state of stiffness. There is a change in the condition of the muscles, and there is a great decrease in sensitiveness to touch and other stimuli. It is a state allied to ' feigning death,' as it is called, in some crustaceans and insects, to the snake becoming a stick, and to some forms of the hypnotic state experimentally induced in man (see SUSPENDED ANIMATION). For some minutes after the experimenter's firm but gentle hand is withdrawn from the crayfish, the animal remains motionless but upside down. Soon, however, recovery comes; it falls on its feet and creeps away, none the worse. There is a long inclined plane, not yet adequately studied, of these states of rigidity and insensitiveness into which many animals pass. In some cases it is probably life-preservative, for there are many hungry animals that do not notice a possible victim until it moves.

On the dorsal surface of the thorax there is a six-sided, single-chambered heart, containing only pure blood, which it drives to the body. Contrast this with the heart of a fish, on the *ventral* surface, two-chambered, containing only *impure* blood, which it drives to the *gills*. This is enough to show that the crayfish, a crustacean Arthropod, is very far removed from a fish, a Vertebrate.

Yet both types are adapted to life in water, and both breathe by gills. Here again, however, the deep difference of type is illustrated. The crayfish has twenty pairs of feathery gills, which are outgrowths of the body-wall, whereas a fish has rarely more than four or five pairs of gills, which are outgrowths of the walls of the pharynx and are separated by **gill-clefts.** In a crayfish the action of the ' baler ' scoops the water out in front of the gills, which are overlapped by the gill-cover, so that a current is always passing into the gill-chamber from behind and below, and passing out in front of the mouth. In ordinary bony fishes the water passes in by the mouth-opening and out by the gill-clefts, washing the gills as it goes. In both cases the gist of the matter is the same; but the structures involved are different and the mechanism is different.

It is instructive to place the gill of a crayfish and the gill of a bony fish side by side in a glass dish against a dark background. In both cases the gill shows a large surface, but that of the crayfish is much the more feathery. It is like a country with a very large coast-line, and the obvious meaning is that the blood, which circulates inside the gill, is exposed on an extensive surface, so that the exchange of gases

is made easier. What is the exchange of gases? Oxygen mixed with the water diffuses into the blood; carbon dioxide diffuses from the blood into the water. The capture of oxygen is facilitated by the presence of an almost invisible respiratory pigment—**haemocyanin**—which has a strong affinity for oxygen. It is allied to the **haemoglobin** (see INDEX) of backboned animals, but the former has copper where the latter has iron. Both are *proteins*—nitrogenous carbon-compounds of great complexity. Another difference in the two cases is that the haemocyanin is in the fluid of the blood, whereas haemoglobin is carried by the red blood corpuscles. The blood that loses oxygen and gains carbon dioxide in travelling through the body of the crayfish passes to the gills and is 'purified'; that is to say, it gains oxygen and loses some of the carbon dioxide. From the gills the pure blood passes to the heart, whence it is driven by arteries through the body. The idea of this circulation is quite different from that of a fish, and a scheme may be useful. Let us use capital letters for pure blood, and italics for impure blood.

HEART → ARTERIES → BO*dy* → *venous channels* → *gi*LLS → AFFERENT VESSELS → HEART.

But the scheme for a fish is very different:

heart→*arteries* → *gi*LLS→ARTERIES → BO*dy*→*veins*→*heart*.

An active animal like a crayfish must form nitrogenous waste-products, and these are got rid of by the kidneys which filter out uric acid and another waste substance of a greenish colour called guanin. The kidneys lie in a strange place, at the base of the feelers; and perhaps it is worth while recalling the fact that the crayfish swims tail foremost. The reproductive organs—the ovaries producing eggs or the testes producing sperms—lie below, behind, and in front of the heart.

Crayfishes are very palatable, and are much appreciated on the Continent. The excuse usually offered for their neglect in England and Ireland is that they are not numerous enough; but over a hundred can sometimes be caught in an evening within fifty miles of London. They may be pulled out with a hooked stick, or caught with the help of a hand-net and an electric torch. They are often captured in a hoop-net baited with frog or liver, and an old-fashioned method was to sink a baited tangle of brushwood, amid which the crayfishes were hopelessly enmeshed.

The European genus of crayfish is called *Astacus* or *Potamobius*, and it is represented on the Pacific slope of North America. But in the American rivers that flow into the Atlantic the crayfishes or craw-

fishes belong to another, though nearly related, genus, called *Cambarus*. Some of the species do considerable harm by burrowing in the banks of streams and mill-dams. An interesting form, *Cambarus pellucidus*, lives in the darkness of the Mammoth Cave and similar caverns in Kentucky and Indiana; and its special interest is that it is almost blind. There are many other cases of more or less blind cave-inhabiting crustaceans, and the difficult question is whether they have become blind because they have lived for many generations in darkness, or whether they are the descendants of weak-eyed individuals who took to dwelling in darkness. We must not be too confident as yet in the answer we give to this long-standing puzzle.

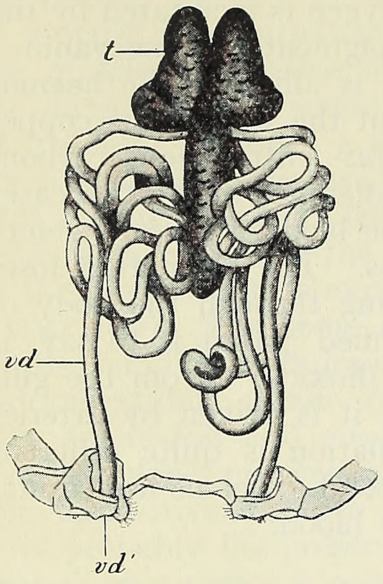


FIG. 100. REPRODUCTIVE ORGANS OF MALE CRAYFISH. —After Huxley

t, testes; *vd*, vas deferens; *vd'*, opening of vas deferens on last walking leg.

Another relative of the freshwater crayfish, that often receives its name, is the Norway lobster (*Nephrops norvegicus*), common in some deeper parts of the North Sea (see Fig. 90). It has a beautiful carroty colour and a finely sculptured, graceful shell, often eight inches long. The young stages are very attractive animals in an aquarium, but their appetite is very assertive. There seems to be a segregation of the sexes in

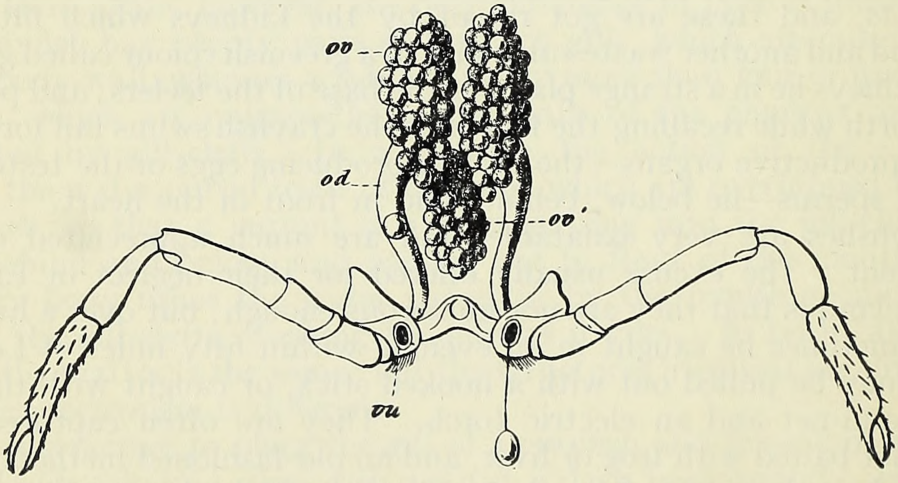


FIG. 101. REPRODUCTIVE ORGANS OF FEMALE CRAYFISH.—After Suckow

ov, ovaries; *ov'*, fused posterior part of ovaries; *od*, oviduct; *vu*, female aperture on the second walking leg.

the sea, for those that are brought to market are almost always males. In a big box of a hundred there may not be a single female.

The most prominent distinctive feature of Nephrops is the elongated and rather slender great claw.

LOBSTERS.—In spite of their somewhat undignified name and a lack of daintiness in their meals, lobsters suggest the aristocracy. They are impressive, handsome, very sure of themselves, and unafraid. The common bluish species, *Homarus vulgaris*, with enormous claws, is one of the finest exhibitions of animal armour and weapons. The rock-lobster, or *langouste* (*Palinurus*), has not huge claws, but it is even more decorative than the common lobster, and as it has a reddish colour when living it deserves its well known nickname, 'the cardinal of the sea.' It is really much more nearly related to the shrimps and prawns than to the common lobsters.

American lobsters may attain to a length of twenty inches and a weight of twenty-five pounds; and the same species in Europe may be almost if not quite as big. So that they are giants among crustaceans, though surpassed in reach by the Japanese giant-crab (*Macrocheira*), which may cover eleven feet from tip to tip of the great claws or chelae when these are outstretched in opposite directions—almost as much as the span of the wings of an albatross (eleven feet eight inches).

Among the boulders of the shore at Roscoff in Brittany we saw some years ago a great lobster pond which was being stocked with fresh supplies that had come in a schooner from Portugal. The Breton boys were unloading the gorgeous freight, and the state of their hands showed that their work was not without its risks. They filled boxes from the hold, and these were swung up over the rock-rampart to the side of the pond. Each lobster in turn was then seized by a fisherman, who with a clever wrench of a heavy chisel put the great claws on both sides out of joint. This was said to be necessary to prevent furious fighting and serious maiming in the pond. In the first pond the lobsters were sifted, the less vigorous being taken out and sent at once to market, while the others, after a fortnight or so, were passed on to a still larger pond, where they were fed for a long time. They were fed generously on dog-fishes, hundreds of which were being dried on the rocks near the pond. As the dog-fishes are very destructive to more valuable fishes, their conversion into lobster is doubly profitable.

It was very interesting to peer into the clear deep water and watch the movements of the handsome animals, so suggestive of knights in armour. There were squadrons of common lobsters in dark blue, and squadrons of rock-lobsters in purple-red mingled with a little blue and with some orange at the joints. One lobster advanced, another retreated; they formed into little groups and scattered again. There were hundreds—indeed thousands of them—a great submarine army. Some were approaching two feet in length of body, with feelers nearly

as long. Some looked as if they had been many months in the pond, for they had great growths of seaweed on their carapace and even on their limbs. In some cases the growth was so thick that it amounted to a disguise, recalling the *masking* (p. 202) of spider-crabs in the rock pools. Many of the common lobsters showed traces of past battles; one giant had a big tuft of seaweed growing on the end of one of his antennae, and carried it like a flag! They feed, they grow, they moult, and grow again—and eventually they are sent by train to Paris. It is very unlikely that man will ever tire of 'lobster,' and lobster fishing is a profitable and healthful calling.

We have spoken of the lobster as an unsurpassed instance of armour and weapons. The armour is very effective, but it is also very elegant; it is hard, and yet the number of joints allows of great freedom of movement; it is callous in itself—being non-living—and yet it is well provided with sensitive bristles. The great claws are very formidable weapons, especially in the male. In this connection it is interesting to notice that lobsters are usually either right-handed or left-handed, the great claws being unequal. The larger and stronger one, which may be either the right or the left, is used for crushing, the other for cutting. Only occasionally are there crushing claws or cutting claws on both sides. It may be noted that among animals with general **bilateral symmetry** (see INDEX) it is very common to find some asymmetry in detail. Thus the stomach in backboned animals lies to the left side; a snake may have only one lung, and a bird has only one ovary.

On the lobster's fine equipment of armour and weapons there is levied the tax to which we have already (p. 207) referred—**moulting.** This is often a heavy tax, for the moulted lobster is soft like wet chamois leather, and the new shell takes about six weeks to harden completely. This gives the lobster's enemies their opportunity. But that is not all, for the moulting or cuticle-casting sometimes involves breakage, and is not infrequently fatally fatiguing. It may be noted that lobsters, like other long-tailed crustaceans, differ from crabs in the order of their moulting, for they get the front part of their body clear first, whereas crabs begin with their tucked-up tail.

Why does a moulted lobster sometimes eat its own 'cast' when its jaws have become hard enough? There seems to be constitutional hunger for limestone, for a considerable quantity is needed to stiffen the new shell. There is an internal source of supply in what are called the "crab's eyes" or gastroliths that form before moulting in the lobster's gizzard. These are concretions of limestone, like tabloids in thickness, the size of a sixpence, perhaps, or of a nickel, according to the age of the lobster. Their history is interesting. They begin to be formed long before the moulting, and they probably consist of limestone that has been absorbed from certain areas of the shell, making

it more elastic for the difficult process of moulting. When the actual casting of the cuticle begins, the two ' eyes ' are unfastened from the internal walls of the gizzard and are dissolved. The calcium salts they contain are absorbed by the blood and go to help the hardening of the new shell. It is said that if the ' eyes ' are not properly developed the ' moulting ' is apt to be fatal; but we are not informed how the initial deficiency is recognized. Being somewhat strange objects, the ' eyes ' used to be credited with remarkable virtues in medicine. A lobster ten inches long and four years of age has moulted twenty-five times, so that we may well speak of moulting as a serious tax.

Lobsters vie with crabs in their powers of self-mutilation or autotomy. The surrender of a damaged or imprisoned leg takes place across a preformed breakage-plane at the joint between the fused second and third basal joints of the limb; and there is the same bandage-membrane as in crabs. Under the shelter of this a new appendage is gradually built up in miniature, and is liberated at the next moult; but several moults occur before the regeneration is perfect. An interesting point is that the breakage-plane is not established until the larval lobster is moulting for the fourth time. Also significant is the fact that the reflex surrender of a limb does not occur if the lobster is put under chloroform. The nerve-centre for the limb must be in proper working order.

The lobster's usual breeding time is about August, when the ' hen ' is seen with numerous berry-like eggs glued on to the swimmerets of her tail. But whereas a big crab may carry three million eggs, the maximum number for a lobster is 160,000, which is attained when the animal is about eighteen inches long. After that the number steadily decreases. Moreover, it is only every second year that the female produces eggs. How is it that lobsters can flourish with such a small number of eggs as compared with crabs? Part of the answer must be that the larva that emerges from the lobster's egg is at a stage much more advanced than the zoaea of a crab. Thus the infantile mortality is lessened.

The development of the lobster is very slow, for the eggs which are liberated on to the swimmerets in August will not hatch till June of the following year. The emerging larva is described as a ' Mysis ' stage, because it is very like a little old-fashioned crustacean called *Mysis* (p. 193), which is a much less evolved type than the lobster. The Mysis larva is far from being a miniature lobster, for it has no tail appendages, and its thoracic appendages—the future walking legs —are two-bladed (bi-ramose). When just hatched it is about a third of an inch in length. It swims about on the surface of open water. After five or six months of this pelagic life, the larva changes into a

miniature lobster, half an inch long, and sinks to the floor of the sea at a considerable depth. It creeps gradually up the slope towards the shore and spends its adolescence in shallow water. When the lobsters become mature they move out again to greater depths, where the fishermen catch them in baited lobster-pots.

One form of lobster-pot is a wooden lath frame with a net at each end, and in the middle of the net a circular opening. The pot is batied with decaying fish, for lobsters are not dainty feeders. The pot is sunk with weights at a suitable place, and is marked by a float at the surface. The hungry lobster makes its way in at the opening, but cannot get out again. After a time the pot is drawn up to the surface.

As we have mentioned, the rock-lobster (*Palinurus*) is more nearly related to the prawn than to the lobster. It has a very remarkable larva, with a flattened-out, transparent body and very long legs. It is called a *glass-crab* or *Phyllosoma*. It looks very strange, yet it may be regarded as a flattened-out 'Mysis' larva. No one seeing it could guess that it was going to become a rock-lobster; it is a larva well adapted for an easy-going life in the Open Sea—in the Mediterranean, for instance.

RED AS A LOBSTER.—As a side-study in colour, let us think over the pigments of the common lobster. The brilliant red of the lobster that lies on the fishmonger's slab is, of course, not the colour of the living animal, though it is not so very different from the reddish-brown of the living langouste or rock-lobster (*Palinurus*). A live lobster (*Homarus*) is blackish-blue, and the colour changes to red during the cooking. As Samuel Butler wrote:

And like a lobster boiled the morn
From black to red began to turn.

In any case there is nothing to fuss over, for the redness and the blueness are due to the same pigment, **zoönerythrin** (p. 212) or 'animal red.' This is a widely distributed pigment among animals, occurring, for instance, in all the higher crustaceans, like crabs and lobsters, shrimps and prawns, and in the red splash above the eye of the grouse. It is almost the same in chemical composition as the familiar **carotin** of carrots. The point must be made clear that there is no special interest in a prawn and a carrot having a similar ruddy *colour*; but there is very considerable interest in the fact that the *pigments* of the animal and of the plant—zoönerythrin and carotin—are almost the same chemically. A physiological understanding of the redness of the lobster may be reached through discovering something more about the redness of carrots. It may be mentioned, however, that the street-boy who cries 'Carrots!' after his red-

haired friend is not on sound bio-chemical lines. The redness of red hair is not due to zoönerythrin, but to a variety of the common dark pigment **melanin**, which belongs to a quite different series. Melanin does not occur in the lobster, or in any of its relatives except shrimps (*Crangon*), but it is common in crabs and other short-tailed crustaceans.

A rock-lobster is reddish, and the Norway lobster (*Nephrops*) is redder, and a boiled common lobster is still more red, because of the presence of the pigment zoönerythrin (better, as Verne says, called *zoöerythrin*), which can be artificially isolated in the form of crystalline needles. It occurs in purest form in pigment-cells (or chromatophores) in the skin; it also occurs in association with fats in the blood, or combined with an albumin in the hard shell, or in the lobster's eggs—which look like coral beads when boiled.

The normal position of the pigment-cells containing zoönerythrin is in the lobster's skin, but to understand this requires a little patience. The shell or carapace of the crustacean is a non-living **cuticle**, made and remade by the underlying living skin. As we have already noticed, it is moulted periodically as long as the animal continues growing; for it has no power of growth in itself, being devoid of cells. It consists of (*a*) calcium carbonate, (*b*) an organic skeletal material called **chitin**, and (*c*) the pigment zoönerythrin. The shell shows three distinct layers, and the pigment is in the middle one. The outermost layer appears homogeneous and clear; the others are stratified; all are traversed vertically by fine fibres which arise from the combination of fibrils in the epidermal cells. There are also very delicate canals passing outwards, but without actually opening to the exterior. Now, all this shell is made and remade by a sloughing off of the moribund outermost portions of the living **epidermis**; and on the inner aspect of the latter there is the under-skin or **dermis** with connective-tissue cells and blood-vessels. In the meshes of the dermis there are the irregular, somewhat amoeba-like, contractile pigment-cells or **chromatophores**, in which the zoönerythrin is produced. They belong to the dermis, but some of them push their way outwards among the epidermal cells. The pigment may pass from the chromatophores into their surroundings, and part of it is deposited in the formation of the carapace. It follows that as long as the crustacean is growing and moulting it must be losing zoönerythrin; but it is probable that a larger amount is always being oxidized in the blood and tissues.

Verne calls attention to an interesting fact in regard to the chromatophores containing zoönerythrin. They are found only on those parts of the skin that are directly illuminated. That is to say, they are practically restricted to the dorsal surface of the crustacean. An apparent exception is to be found in the presence of red pigment-cells on the dorsal surface of the soft tail of the hermit-crab, which is

sheltered within the thick borrowed shell of a *Gasteropod* (q.v.). But in a pretty experiment Mercier has shown that the interior of the shell tenanted by the hermit is by no means a dark chamber, as far as the chemical influence of the light is concerned. Thus the apparent exception proves the rule; direct illumination is required for the development of the red pigment-cells.

The question now arises: Where does the zoönerythrin come from? Some physiologists have suggested that it is derived from the food of the crustaceans, but this theory does not work well. Take a single point: the colour of butter disappears when the cows are not allowed to have their natural herbaceous diet, which keeps them supplied with carotin or some related substance; but crustaceans starved for a long time show no reduction of red pigment-cells. There is strong evidence in support of Verne's conclusion that zoönerythrin is elaborated in the pigment-cells of the crustacean's skin under the stimulus of light. From an uncoloured carbon-compound—possibly allied to the common substance called *cholesterin*—there is formed the red pigment. This is how the lobster is red or blue, as the case may be. For the *colour* as such does not seem to be of much, if any, importance in lobsters. The eggs of the carrot-coloured Norway lobster are green.

But the lobster has a second pigment, quite apart from zoönerythrin. It has a yellowish or whitish colour, and appears in irregularly branched pigment-cells in the skin. It is of general occurrence in crustaceans, and it has been named by Verne the **amino-acid pigment.** The reason for the name is that the pigment arises from a disintegration of nutritive protein substances carried by the blood; and an invariable stage in the breaking down of a protein (such as the albumin of white of egg, the casein of cheese, the gluten of wheat) is an amino-acid. When we turn a common lobster upside down we see a good deal of yellow colour, which is due to this amino-acid pigment. And as the yellowish chromatophores deposit in the carapace some of the material they make, there is a loss of amino-acid pigment at every moult, just as there is a loss of anthocyanin and other pigments in the withering leaves which fall in autumn from the trees.

If we were dealing with crabs instead of lobsters, we should have to go on to a third pigment—**melanin**—of a dark colour. But, as we have already mentioned, this does not occur in any of the common long-tailed crustaceans except shrimps (*Crangon*). Verne's account of the origin of melanin is very interesting. It is formed, at the expense of the amino-acid pigment, as a by-product in the protein-disintegration that is always going on in a living body. Its formation requires the presence, first, of *tyrosin* as one of the products of the protein-disintegration, and, second, of an oxidizing ferment or *enzyme* called *tyrosinase*. In these conditions the dark melanin replaces the

yellowish amino-acid pigment. Many naturalists are anxious to find utilitarian interpretations of pigments, and this is a thoroughly justifiable search. But it should be remembered that the physiological inquiry comes first: How do these pigments come to be? A bar of zinc, exposed in damp air, forms an outer layer of basic zinc carbonate; and one may, if one chooses, say that this outer layer is protective against further 'rusting.' Yet it *had to be*. In the same way, while melanin may protect an animal against over-illumination, the primary fact is that in certain conditions it *has to arise* as a by-product in protein-disintegration.

HERMIT-CRABS.—Among the commonest and most interesting of seashore animals are the hermit-crabs. The best known British species is *Eupagurus bernhardus*, which occurs from rock pools to deepish water with great diversity of size. The smaller inshore hermits, living in the borrowed shells of periwinkle and dog-whelk, have blue tails; those that live further out, tenanting the shells of the roaring buckie and the giant whelk, have red tails; but it is the same species with the same pigment (*zoönerythrin*) in both cases. These hermit-crabs are very satisfactory seashore animals to study, for they do not hide their 'habits,' and they are enterprising adventurers. If they are kept in a large milk basin, with frequent changes of water (easy enough to secure on seashore holidays), and if they are rationed judiciously on animal food, with neither too much nor too little, they remain lively for a long time. And if they die they are readily replaced.

We soon become accustomed to the strange sight, but it is amusing to see what looked like the empty shell of a periwinkle suddenly take legs to itself and scuttle away. Very cautiously the head comes out, showing the stalked eyes, the short, quivering antennules (with a balancing organ at their base), and the graceful, mobile longer antennae. Then the great claws appear, the right one always much the larger. Behind these are two pairs of long walking legs, the other two pairs being short and not exposed. At the end of the tail region there is a pair of strong, somewhat sickle-like, appendages, which grip the borrowed shell with great tenacity. The other tail appendages are on the left side only; the male is said to have three, all small; the female has four, the first three strong and used for carrying the eggs after these are liberated. The hermit moves quickly on its two pairs of walking legs; but it experiences some rebuff, and instantaneously it is once more a periwinkle shell! The rapidity of the reflex back-jerk is remarkable; and another rapid flick, not so often seen, is the vaulting from an old shell into a new one. When it has found a new house to satisfy it, the hermit flits like a flash. During its growing period the common hermit-crab may try half a dozen or more kinds of Gasteropod shell, especially

periwinkle and dog-whelk, but not infrequently the top-shell (*Trochus*) and the turret-shell (*Turritella*). When it grows big it usually restricts itself to the shells of the buckies or large whelks (*Buccinum* and *Fusus*). There is no convincing evidence that it ever attacks a living sea-snail and tries to oust it forcibly from its shell. Some strong evidence of this violence has been adduced, but Dr. Gordon Jackson, an authority on hermit-crabs, suggests that the apparently aggressive individuals that have been observed in the act of tearing away at a recently dead whelk are dealing with the victims of the cod's voracity. The cod is fond of large whelks, and it sometimes bites off the mollusc's expanded head and foot. What the cod began, the hermit completes, and it may finish up by flitting into the house it has helped to empty.

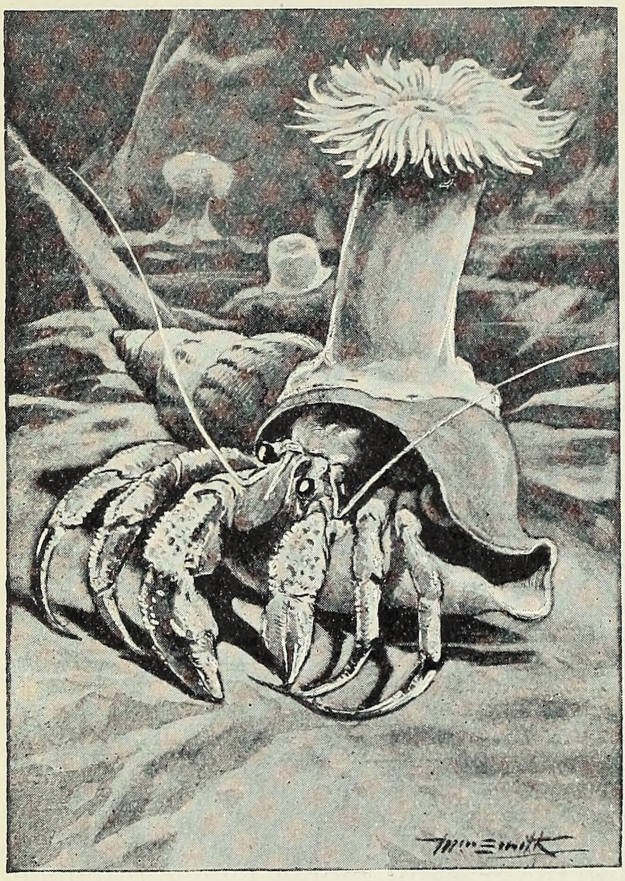


Fig. 102. Hermit-crab and Sea-anemone

The covering or cuticle of the hermit-crab's body is soft as compared with a lobster's or a true crab's. Only the great claws and the two anterior pairs of walking legs show the usual hardness. In other words, while the body is covered as usual with a cuticle of chitin, there are, except in the parts mentioned, only slight deposits of limestone. Nevertheless the hermit-crabs have to moult just like lobsters and crabs, and here we may recall the fact that the outer investment or cuticle is non-living and therefore cannot increase in size to meet the animal's growth. Hence the necessity for moulting. In the fatiguing process the hermit withdraws his anterior body first, then the muscles of the legs out of their husks, and thirdly, the tail region. The cast cuticle is like a ghost of its previous tenant, who proceeds to make a new covering without any delay. But the point is that while all growing crustaceans have to pay this moulting tax on growth, the growing hermit has also to change its house.

The hermit's bill of fare is a long one. The creature has so catholic an appetite that it will eat almost anything. It is fond of animals, whether living or dead; but it sometimes eats seaweeds. The left great claw is chiefly used in transferring food to the three pairs of chewing foot-jaws which lie beside the mouth. There is much fighting between full-grown hermits, but it is only in the larval life that there is cannibalism. A quaint fact in connection with meals is the frequent presence of a marine worm (*Nereis fucata*) in the recesses of the hermit's borrowed shell. It usually keeps in the background, but when the crustacean is having a meal the worm comes forward and appropriates morsels of food just as they are passing into the mouth. This rather one-sided companionship is so common that the fishermen in some places collect the hermit-crabs for the sake of the worms, which they use as bait. But the twisted, banana-like tail of the crustacean itself is also used in this way, especially for cod, and the whelks are usually regarded as better still.

In the Firth of Clyde and other western Scottish waters a very common hermit-crab is *Eupagurus prideauxii*, which is invariably associated with a sea-anemone called *Adamsia palliata* (see Fig. 102). After it attains a certain size this species of hermit-crab ceases to change its borrowed shell, but relies on the sea-anemone, which forms a protective cape that can be extended as the crustacean's growth continues. Sometimes there is only a remnant of mollusc shell, and sometimes there is none at all. If Prideaux's hermit does shift from one mollusc shell, e.g. *Natica*, to another, it is said to be able to transplant the sea-anemone, though, on the face of it, this seems impossible! We have here to do with **commensalism** (see INDEX), which may be defined as a mutually beneficial external partnership between two animals of different kinds. The hermit has the advantage of being not only protected but masked by the sea-anemone, which, in turn, has the advantage of transport and of getting crumbs from the hermit's frequent meals.

No one can watch these pugnacious hermit-crabs in the rock pool without wondering where they came from. The answer is not so satisfactory as might be wished, for no one has actually observed the liberation of the eggs on to the female's tail, or the transference of sperms from the male to the female. We know, however, that the fertilized eggs are found attached, in purple clusters, to the bristles on the female's second, third, and fourth abdominal appendages. There they develop at all seasons of the year, and thence there emerge the minute free-swimming larvae. The female hitches herself partly out of her borrowed shell and brushes her offspring into the water. There are four free-swimming (*Zoaea*) stages, punctuated by moults. Then comes a short strange phase of metamorphosis, called the *Glaucothoë*.

This larva lives on the floor of the sea by day, and swims at the surface by night. In a few days it puts on the peculiarities of a hermit-crab. The sixth chapter is adolescence, which lasts for about a year. The first borrowing of a tiny shell is during the Glaucothoë stage, but the changes to the hermit-crab appearance are independent of a shell, though its absence usually proves fatal.

The most interesting questions in regard to hermit-crabs are the most difficult to answer. Is their lack of symmetry the hereditary outcome of living in asymmetrical Gasteropod shells? An Indian Ocean hermit that lives in pieces of bamboo is quite symmetrical. Yet the Glaucothoë larva of ordinary hermit-crabs puts on asymmetry even if it is kept naked. Or again, is the hermit's tail soft, sensitive, and almost inflamed because it is kept sheltered inside the borrowed shell, or does the animal borrow a shell because it has so soft a tail? Yet some people say they know all about hermit-crabs!

LARVAL CRUSTACEANS.—As we have already noticed, the word *embryo* is applied to the early stages in development within the egg-envelope or egg-shell. When the egg is hatched, there emerges either a *young creature*, as in the case of a chick, or a **larva**, as in the case of a tadpole. The larva differs from an embryo in being free from the egg-envelope, and in being able to fend for itself. It differs from a young creature because it is not yet like a miniature of the parent, but has peculiarities of its own which are often markedly adapted to conditions very different from those of adult life, as is obvious in the contrast between larval caterpillar and adult butterfly.

There is a general tendency towards individual **recapitulation** of racial history, and in some cases the occurrence of larvae means that a particular chapter in this recapitulation is emphasized and lengthened out. Thus the free-swimming larva of a sedentary sea-squirt or Tunicate is in all probability something like the ancestral form of these strange animals, and the symmetrical larva of the very unsymmetrical flat-fishes (such as plaice and flounder) is also a recapitulation. But the difficulty is that the larva may be specially and secondarily adapted to suit peculiar conditions, and may thus show characters that are far from being ancestral. Thus the flattened *glass-crab* larva of the rock-lobster may show ancestral features in some of its limbs, and so forth, but no one can suppose that it is ancestral as regards its flattened shape. It is suited for an easy-going youthful life in the Open Sea.

MEANING OF LARVAE.—There is no doubt that larval stages are interpolations on the direct sequence of development. It is as if the animal diverged for a time from the direct route and came back to it again. What advantages are there in the roundabout road? Why have some animals larval stages, while others have not? (1) One

advantage is that the larvae get away from a difficult haunt until they gain strength. Thus many shore animals have Open-Sea larvae. (2) Another advantage is that the young stages may be able to scatter and get away from their crowded birthplace. Thus many sedentary animals, such as sea-squirts, moss-animals, and lamp-shells, have free-swimming larvae. (3) The advantage of the larval period may be to accumulate nutritive reserves which are used to build up a more elaborate body during a period of metamorphosis. Sometimes, as in caterpillars and butterflies, the larval period may be the chief nutritive chapter in the life-history, while the adult chapter is mainly reproductive. (4) In other cases the interpolation of a long larval period may be a way of circumventing the seasons. Thus for butterflies and moths it is on the whole easier to survive a northern winter as caterpillars or as chrysalids, than as adults.

Among the lower crustaceans, such as water-fleas and acorn-shells, the commonest larva is a **Nauplius,** usually microscopic. It has a somewhat shield-like unsegmented body, with an unpaired median eye, and with three pairs of appendages, the first unbranched, the other two bi-ramose. They correspond to the future antennules, antennae, and mandibles. The head region of the nauplius becomes the head region of the adult; the posterior region also persists; the new growth of segments and appendages takes place (punctuated by numerous moultings) between the two.

The second important form is the **Zoaea,** which has a segmented abdomen and appendages as far back as the foot-jaws (or maxillipedes) inclusive. It has gained two lateral compound eyes. There is usually a long spine on the back of the head-and-breast (cephalothorax) shield. Most of the highest crustaceans, the Decapods, are hatched out in the Zoaea stage, and a crab is a good example. A common size of a Zoaea is a pin's head.

As has been noticed, the common lobster is hatched out as a **Mysis,** without abdominal limbs as yet, but with the future walking legs two-bladed or bi-ramose and suited for swimming.

It is useful to think over the contrast between the life-history of the freshwater crayfish (*Astacus*) and that of *Penaeus*, a kind of shrimp. In the latter the first chapter is a nauplius, this changes into a zoaea, this is followed by a ' Mysis ' stage, which changes into the adult form. The different chapters are separated by moults. But in the crayfish there has been a telescoping of larval stages within the egg, and what is hatched out is almost a miniature adult. This, as we have already said, is in relation to the risks to which larval stages are exposed in rivers.

It should be mentioned that there are often intermediate stages; thus there may be a meta-nauplius and a proto-zoaea between the

nauplius and the zoaea stages, and a meta-zoaea between zoaea and 'Mysis.' It is an intricate and a hazardous 'Mirza Bridge,' with many chances of death, which these young crustaceans have to cross.

Natural History of Crustaceans

Many of the great ideas of Natural History are well illustrated among crustaceans. Thus the **circulation of matter** is often striking. (*a*) The mackerel feed largely on the Copepod crustaceans of the Open Sea, but these depend on Infusorians and Diatoms. (*b*) The vegetable débris at the side of the freshwater pond is worked at and rotted by bacteria; these are devoured by Infusorians; these form food for the minute crustaceans called water-fleas, which are eaten by fishes, which are eaten by man. (*c*) Rotted leaves produce nitrates and the like which form part of the food-supply of vigorous aquatic plants, on which freshwater snails may be seen browsing. But the trout are fond of the water-snails, and the anglers are fond of trout. Thus matter passes from one embodiment or incarnation to another.

Another leading idea in Natural History is the **linkage** of one life to another; and of this there are endless instances among crustaceans. The sand-crab, *Hyas areneus*, nibbles at seaweed and fastens piece after piece on to the bristles of its shell. Thus it goes about with a garden on its back and illustrates **masking.** Other crabs utilize sponges; others cut off the tunics of sea-squirts, and use them as cloaks. There are many instances of mutually beneficial partnership or **commensalism** between hermit-crabs and sea-anemones, or between ordinary crabs and sea-anemones. The crustacean is concealed and protected, sometimes even armed; the anemone is carried about and gets its share of meals.

As has been indicated, the number of parasitic crustaceans is legion, and they are very interesting in their diversity. For some are external, like fish-lice; others get into the interior, like the *Sacculina* of crabs—a case of crustacean on crustacean. In some cases the male animal is free, while the female is parasitic, this being associated with the need for sheltering the offspring. But a parasitic female may carry a pygmy parasitic male; and other strange things happen.

The diversity of habitat among crustaceans is also noteworthy. While the vast majority are marine, the wood-lice have become entirely adapted to terrestrial life, and there is a good representation in fresh water, from tiny water-fleas to the crayfish. The robber-crab climbs the stems of the coco palms. A large number live in the great abysses; others find a refuge in the darkness of caves.

Not much is known in regard to the intelligence of crustaceans. Lobsters, hermit-crabs, and true crabs are business-like, effective

creatures, but from our study of autotomy it must be plain that what looks at first sight like great shrewdness is probably mere automatism—at least as it occurs nowadays. Perhaps its racial enregistration involved some intelligence. Crustaceans illustrate (1) reflex actions, as when an affronted hermit-crab jerks itself back into its shell; (2) tropisms or obligatory movements, as when a crayfish moves into the shade, or certain kinds of free-swimming larvae make persistently for the light; and (3) instinctive activities, as when a hermit-crab without a shell exerts itself to find one. When a hermit-crab is about to flit from a Gasteropod shell for which it has become too large, it goes about exploring among the available empty shells, to see, as we might say, if they will suit. It looks like a man seeking for a house! But we become less sure of the accuracy of our generous interpretation when we notice that a comfortable hermit-crab at leisure cannot help examining an empty shell, even when it has no need of one at the time. It has to obey its instinctive prompting to look into empty shells.

Mlle Drzewina supplied a number of naked-tail hermits with empty top-shells (*Trochus*), a kind of shell that they appreciate. The shells were very suitable, as far as shape went, but the mouth of each was closed with a cork. The hermit-crabs spent a whole night trying to draw the corks, but all in vain. They continued the exploration next day, but gradually abandoned the attempt. After four or five days, when they happened to touch a corked shell in their wanderings, they drew back just as they do when a shell is inhabited by its rightful tenant, and this they did although they were badly in need of a shelter for their sensitive tail. After six to eight days they had lost all interest in top-shells; so that we may say that a negative association had been established. A sort of taboo had been formed. But when Mlle. Drzewina gave them shells of entirely different form, also corked, the hermits tried them eagerly, though of course in vain. They had not appreciated, as an intelligent child would, what was wrong with the top-shells. And when they were supplied with top-shells with only paper in the mouth, which the hermits could easily have torn off, they would not look at them. A forceful association had been established, and this illustrates the beginning of learning, though at a very non-intelligent level. Crustaceans are able to form associations, but their intelligence is still very feeble. See our *Minds of Animals* (London, 1927).

CHAPTER XII

MYRIAPODS AND THEIR RELATIVES

Air-breathing Arthropods—Peripatus and its allies—Centipedes—Millepedes—Convergence.

AIR-BREATHING ARTHROPODS.—In all animals there is a capture of oxygen from the surrounding medium. It may be the oxygen that is mixed in the water, and that is true of the great majority of crustaceans; but it may be the oxygen of the atmosphere; and this is the mode of respiration in the animals to which we now proceed to study —the **Tracheata antennata.** They include the old-fashioned Claw-bearers or *Onychophora*, the Centipedes, the Millepedes, and the enormous multitudes of Insects. They are called *Tracheata* because they all have air-tubes or **tracheae,** which carry air into every hole and corner of the body. They are called *Antennata* because they all bear **antennae** or feelers—a single pair—on the front of their head. *Crustaceans* have usually two pairs of antennae; spiders, scorpions, and other *Arachnids* have no antennae at all; but the claw-bearers, the centipedes, the millepedes, and the insects have one pair of antennae.

Let us look at the alliance of *Tracheata antennata* in another way. For untold ages there was an abundant population of aquatic animals —mostly marine. Gradually there began to be a colonization of the dry land, and, as we noticed in connection with earthworms, the first great invasion of terra firma was on the part of worm-like animals, which absorbed oxygen through their moist skin. But the second great invasion was on the part of air-breathing jointed-footed animals or Arthropods, and of these invaders the old-fashioned type called *Peripatus* is the oldest living representative. The air-breathing crustaceans such as the wood-lice were much later invaders and much less important. But the Arthropods are characterized by the possession of a non-living chitinous cuticle which covers the living skin; and this raised a difficulty that the earthworms had not to meet. A chitinous cuticle shuts in the living skin, and this makes the absorption of oxygen a difficult matter. The solution discovered was the development of internal surfaces for oxygen-absorption. In other words, there was an evolution of ingrowing tubes—the tracheae or air-tubes—which carry the atmosphere into the recesses of the body. This was a new idea in evolution. In an earthworm the blood is spread out on the skin; in a gill-bearing animal like a lobster the blood is spread out on the large external surface of the gills. But the new

idea in *Tracheata antennata* was taking the air to the blood, instead of taking the blood to the air. This proved a great success, for there is no class of animals so successful as the class *Insecta*.

PERIPATUS AND ITS ALLIES.—The most primitive class of air-breathing Arthropods is that of the *Onychophora* (*onycho*, claw; *phora*, bearers). Their other title — *Prototracheata* (*proto*, first; *tracheata*, with tracheae)—refers to their primitiveness in the series of Tracheate antennate animals. No one says that Peripatus and its relatives are the first Tracheates; but they are the most primitive known representatives of the group.

The claw-bearers are somewhat caterpillar-like animals, but without external rings or segments. A common size is a couple of inches. There are several genera, such as *Peripatus*, with some representatives in most parts of the world except Europe. This wide distribution is seen in many old-fashioned animals, such as lancelets, and hints at the great stretches of time that have been available for diffusion. The appendages are: a pair of mobile antennae in front of the head, a pair of jaws in the mouth, a pair of slime-secreting oral papillae, and from fourteen to forty-two stump-like legs, very imperfectly jointed, and ending in a couple of claws. There are also two anal papillae of the nature of appendages. The legs contain peculiar (coxal) glands.

Respiration is effected by numerous unbranched tracheae, with fine openings irregularly scattered, a number to each segment (internally indicated) of the body. The heart is an elongated dorsal vessel, with paired valved apertures at intervals. There is a series of paired kidney-tubes or nephridia, segmentally arranged and opening near the base of each leg. No other Tracheates have nephridia. The halves of the ventral nerve cord are widely separate—a very primitive feature —and there are only hints of ventral ganglia. The claw-bearers are viviparous and the young ones are born fully formed.

What gives particular interest to these old-fashioned little animals is their combination of worm-like and tracheate characters. For this reason they are called **synthetic types**, combining Annelid and Tracheate characters in a unique way. This may be indicated in parallel columns:

Annelid Characteristics	Tracheate Characteristics
A double row of kidney-tubes or nephridia.	*Tracheae.*
The muscular ensheathing of the body.	*An elongated tubular heart.*
Stump-like hollow legs.	*Appendages in the service of the mouth.*
Simple eyes.	*A pair of antennae.*
Cilia in the genital ducts.	*The genuine body-cavity or coelom is much reduced.*

The late Professor Sedgwick spoke of the attractiveness of these archaic claw-bearers: 'The exquisite sensitiveness and continually changing form of the antennae, the well-rounded plump body, the eyes set like small diamonds on the side of the head, the delicate feet, and, above all, the rich colouring and velvety texture of the skin, all combine to give these animals an aspect of quite exceptional beauty.'

It is interesting to ask how these antiques hold their own in a world that must have changed greatly since they began to be. (1) They are shy and nocturnal, with a strong dislike to light. (2) They live a hidden (**cryptozoic**) life, lurking in damp places under leaves and among rotten wood. (3) They are able to move quickly, to climb up vertical surfaces, and to coil in a circle when disturbed. (4) They have a unique way of capturing their prey of small insects, for they eject



FIG. 103. *Peripatus*

jets of slime from their oral papillae. They do the same when irritated. (5) It must also make for safety that the young ones are born fully formed, and it is interesting to find that the development is very slow. In one species the mother carries its young one for thirteen months before it is born, which is two months longer than the time (of gestation) during which a mare carries her unborn foal. This illustrates one of the great trends in Organic Evolution—the trend towards *viviparity*, in contrast to egg-laying or *oviparity*. It is one of the ways of circumventing the difficulties of terrestrial life.

It is worth noting that a case is known of a Peripatus being born in Britain. Miss Fordham records that she collected an Australian specimen on the 20th September 1925. It reached Liverpool in January 1926, and gave birth to young ones in April, at least five months after contact with any of its kind. The Western Australian Peripatus is inseminated during the wet season (winter), and there must be a gestation period of about six months, during which the animals remain hidden within decaying wood or in the soil.

CENTIPEDES (CHILOPODA).—Among loose earth, or under bark and flat stones, the inquisitive eye often detects centipedes, but they do not wait to be looked at. With the utmost celerity they hurry away on their many legs, and disappear down some narrow passage. They *row* on the ground with their jointed legs, and while those of one set are being drawn backwards against the ground, thus levering the animal forwards, those of another set are being moved headwards to take grip for another leverage. It all takes place very rapidly, but the

main fact is that the animal is rowing on the ground, and that the legs work in relays.

Centipede obviously means hundred-footed, but the number of legs is very diverse in different kinds, the limits being fifteen pairs in *Lithobius* and one hundred and seventy-three in the *Geophilids*. The number of segments corresponds to the number of pairs of legs, whereas in millepedes there are two pairs of legs to each segment. This is an indication of what will become more and more evident as we continue, that centipedes and millepedes are not nearly related to one another. They form two separate classes, and there is no great advantage in uniting them under the common title *Myriapods*.

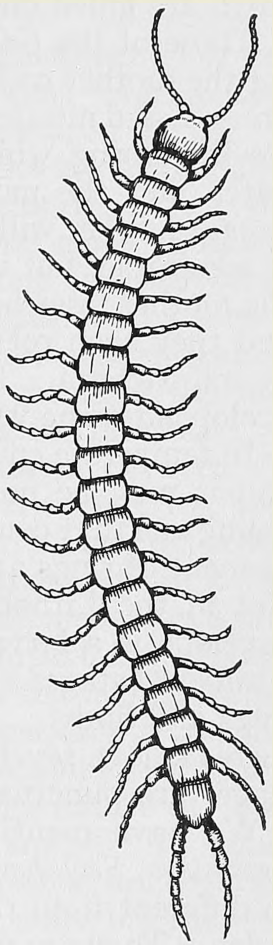


FIG. 104. A CENTIPEDE

Centipedes are marked by the rather flattened body, the strong legs, and the very long antennae. There are three pairs of mouth appendages, just as in insects; and the first of the legs behind the mouth are turned into poison-claws. The terminal legs are always longer than the others, and between their bases the food-canal ends. Just in front of this anus is the single opening of the reproductive ducts.

Centipedes are aggressive carnivorous animals, hunting for living prey, such as insects and insect larvae not too hard in the cuticle, besides earthworms and wood-lice. Occasionally they devour one another, and very occasionally they eat the juicy parts of plants. Their animal victims are paralysed by the injection of poison, and then torn by the mandibles. In some cases a centipede lassoes or binds its booty with sticky threads produced from glands on the last pair of legs.

Centipedes hunt in darkness, and are markedly uncomfortable in the light. They prefer a certain amount of dampness, and two or three species of *Geophilus* live between tide-marks. Centipedes like to have much of their body in contact with the adjacent surface, and this accounts for the way in which they sometimes creep into very inappropriate passages, such as the nostrils. Some centipedes are *luminescent*, some always, and some only in autumn, but the nature of the light is uncertain. Some are annual animals, but in the common genus *Lithobius* three years are needed to attain maturity, and there may be three years after that. The largest tropical centipedes are about eighteen inches long, and Humboldt records that he saw

Indian children dragging them out of the earth and eating them there and then.

In centipedes of the *Lithobius-Scutigera* group the eggs are carried for a short time by the mother, who grasps them in small appendages beside the genital aperture. She then deposits them individually in the soil, where they are practically undiscoverable, since particles of earth are glued on to the sticky egg-envelope.

Those of the *Geophilus-Scolopendra* orders show some *maternal care*, for the mother coils round the little cluster of eggs, keeps them off the ground, and moistens them with a secretion. This care lasts for several weeks, during which the mother fasts. Even after the young ones hatch out, the mother may continue her protection, and the *Scolopendra* mother will fight in defence of her brood. The care of the eggs is admirable, but it is in the main instinctive, not intelligent. For if the mother loses her clump of eggs she seems unable to retrieve them, and they soon rot on the ground. That is to say, they are attacked by soil bacteria. If a clump of eggs be forcibly removed from a mother Scolopendra she will accept a little pebble instead.

In temperate countries the breeding season of centipedes is in spring, and it may be noted that in the Geophilus-Scolopendra orders the young one that comes out of the egg-envelope has already its full complement of rings and limbs. It has only to grow larger and to moult. But in the Lithobius-Scutigera orders, what comes out of the egg-envelope is a larva with only seven pairs of limbs. There follow a number of stages at each of which there is an increase in the number of rings and limbs. When the characteristic specific number is attained there follow several stages which only involve growing. All the stages are punctuated by moultings.

We have mentioned four common genera of centipedes, namely *Geophilus*, *Scolopendra*, *Lithobius*, and *Scutigera*. The Scutigerids are so different from the others that they are often referred to a separate order. They are marked by their very long legs, somewhat like those of spiders. They are common in the Mediterranean region and in parts of Africa, and run about actively in the blazing sun, hunting for small insects. They have faceted eyes, and there is a unique sense-organ below the head.

MILLEPEDES (DIPLOPODA).—Of all the creepy crawling creatures that one sees under the loose sods by the wayside, or among the decaying leaves and twigs in the shady wood, millepedes are probably the least popular. They take rank with centipedes, earwigs, and wood-lice; people don't like them. Perhaps there is something inartistic in the monotonous repetition of ring after ring on the body, each, after the third, with two pairs of limbs. Perhaps there is some vague suggestion of a miniature snake in their rapid rowing on the

ground. It is difficult to account for the prejudice, but it is certainly strong. Personally we have no small admiration for millepedes, and yet we do not welcome one creeping up our sleeve. We wonder if the widespread repulsion has its basis in a disagreeable cutaneous sensation —something worse than tickling. When they are irritated they secrete a yellowish fluid that burns. However the prejudice has arisen, there is no doubt as to the scientific interest of millepedes.

Very long ago, as every one knows, there was a colonization of dry land by worm-like forms that migrated from the water. Ages passed and there was a second great colonization of terra firma, on the part of air-breathing jointed-footed animals. Our millepedes are descendants of the pioneers that made the second great trekking. With the millepedes are associated the centipedes and some more primitive types, the most archaic of all being the claw-bearers (*Onychophora*), represented by the somewhat caterpillar-like *Peripatus*. This then is the first great interest of millepedes, that they are direct descendants of the early jointed-footed invaders of the dry land, pointing the way onwards to their distant and more evolved relatives, the insects.

In more languages than ours a distinction is drawn between the hundred-footed centipedes and the thousand-footed millepedes, both numbers being, of course, more or less imaginative. The two orders used to be included in the class *Myriapods*. But more precise knowledge makes it clear, we think, that centipedes and millepedes have very little to do with one another, their resemblances (apart from fundamentals) being due not to blood-relationship, but to the fact that they are similarly adapted to similar conditions of life, especially to creeping through crannies and crevices in the soil or among decaying vegetation. In other words, their resemblances are largely of the nature of ' convergence,' as between slow-worm and burrowing snake. No doubt there is relationship between centipedes and millepedes, for both are rather old-fashioned generalized air-breathing Arthropods, but they are not so like one another as they look, and no small part of their likeness is the outcome of becoming similarly adapted to an elusive cryptozoic mode of life in the purlieus of the soil and the woody wreck of the forest.

It is a zoological lesson worth learning to recognize that centipedes and millepedes are on different lines of evolution. For centipedes are mostly flattened from above downwards; they have one pair of limbs to each ring; their feelers have many (at least fourteen) joints; there are three pairs of mouth-parts, just as in insects; the first pair of legs is transformed into poison-claws; and there is a single genital aperture on the second last segment of the long body. There may be as many as three hundred and fifty rings, so that the name hundred-footers is often quite legitimate, though thirty-five would, we think, be nearer the average number.

Now, in detailed contrast to these centipedes, millepedes are almost always quite cylindrical; they have two pairs of limbs on every ring after the first three; their feelers have only seven joints; there are only two pairs of mouth-parts; there are no poison-claws; and the genital openings are far forward, often on the seventh segment. It is very interesting that there should be so many points of difference between centipedes and millepedes; it shows that their resemblance (apart from the fact that both are air-breathing antennate Arthropods) is very superficial, and that the class of Myriapods, established to include them both, must be broken up. If this seems very technical zoology, remote from practical affairs, we should note that the divergence extends to habit as well as to structure. For millepedes are vegetarian and innocent, whereas centipedes are carnivorous and poisonous. The gardener often kills them both without discrimination, but this is a mistake, since centipedes are seldom directly injurious to plants, and their destruction means the removal of a useful check to the multiplication of injurious insects.

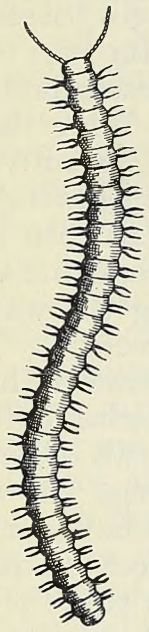


Fig. 105. A Millepede

Let us pass to the life of the millepedes, especially of those that are like our common British *Julus*. The movements, looked at impartially, are very beautiful. Pressing the clawed tips of its many limbs against the soil or the rubbish, the millepede levers itself along, swiftly and lightly, rowing on the substratum with sometimes a hundred pairs of oars. While a certain number of legs are being drawn backwards, thus pressing against the resistant surface and pushing the creature forwards, another set are being drawn headwards to grip the ground in their turn. We see what looks like wave after wave, passing along the row of legs—fascinating to look at, even if we are not sure that we understand what is happening. Meanwhile the short mobile antennae are touching and testing everything, and they carry minute smelling organs on their tips. As the rings of the body are hard, with limestone as well as chitin, their movements produce a slight sound, which some people can hear when everything is very quiet. We never did.

As centipedes have poison-claws they can look after themselves; but how do the millepedes keep their foothold in the unending struggle for existence? Partly, no doubt, because they are ' cryptozoic,' with great power of self-effacement; partly because they move quickly and disappear into crevices; but largely because they have numerous stink-glands with a pair opening on almost every ring, and secreting an objectionable yellowish fluid. This is caustic and has a repulsive smell; it appears to contain prussic acid and sometimes iodine. Thus

the millepede tends to be left severely alone. It may be mentioned that the true wireworm, which many birds devour, is the larva of the click-beetle, whereas the false wireworm is the millepede. Both are 'wireworm' and anathema to the gardener.

Dr. K. Verhoeff, who has been studying millepedes all his life, tells a very remarkable story. Just behind the head of a Julus there is sometimes to be seen a clear globule, which is the egg of a predatory Tachinid fly. The female insect in depositing this egg secretes a drop of acid glue which effects fixation to the millepede's very firm cuticle. But when the larval fly hatches out of the egg it also has an acid secretion with which it dissolves a hole through the partly calcareous cuticle. Thus it gets inside the millepede's body, and there it waxes so strong that it kills its host. The dead millepede falls to pieces, and this seems to be necessary if the young fly is to get out. What wheels within wheels!

One of the vicissitudes in a millepede's life, as long as growth continues, is moulting. The protective cuticle of chitin and limestone is non-living and cannot keep pace with the creature's growth; therefore it is periodically shed, carefully, and we might almost say laboriously, for the muscles of every limb have to be drawn out of their hard ensheathing husk. The animal emerges as soft as wet paper, unable to move or do anything; it grows rapidly before the new cuticle, made by the living skin, has begun to harden. The silvery-white old suit lies for a little like a ghost, and then the animal may eat it up. All this takes place within a secret chamber of undigested humus or mould that has passed through the millepede's food-canal and is mixed up with digestive secretion.

Somewhat in the same way the mother Julus makes a protective envelope round her little heap of eggs, and among the numerous different kinds of millipedes there is considerable variety of maternal care. Of *Julus* in particular Mr. F. G. Sinclair tells us that the mother moistens particles of earth with her salivary juice, and fashions below the surface of the ground a spherical nest about the size of a small nut. It is rough outside, smooth inside, and there is a hole at the top, through which she passes from sixty to one hundred eggs along with some glue that makes them cohere. She shuts the aperture with salivated mould and goes on her way. Minute millepedes hatch out in about twelve days. We have not been able to do more than begin to tell the story of millepedes, but who said they were uninteresting?

Besides Centipedes and Millepedes, but nearer the latter, there are two small orders: (1) the *Symphyla*, e.g. *Scolopendrella*, with a strong resemblance to bristle-tail insects, and with many peculiarities, such as having only a pair of tracheae; and (2) the *Pauropoda*, e.g. *Pauropus*, very minute pale forms with slender bodies, long limbs, branched antennae, and other peculiarities.

CONVERGENCE.—It is instructive to make a contrast between centipedes and millepedes, which the casual observer is at first inclined to lump together. The point of the contrast is that the two classes have very little in common, except that they are many-legged tracheate antennate Arthropods, with a large number of body-rings.

Centipedes or Chilopoda	Millepedes or Diplopoda
Carnivorous.	*Vegetarian.*
Poisonous.	*Harmless.*
Usually flat.	*Cylindrical.*
One pair of legs to each segment.	*Two pairs of legs to each segment.*
Antennae with many joints.	*Antennae with few joints.*
Three pairs of mouth appendages.	*Two pairs of mouth appendages.*
Genital aperture single and posterior.	*Two genital apertures near the head.*

But the question arises: Why are these two classes of animals superficially like one another, though so different in detail? The answer is that they are similarly adapted to similar conditions of life—to creeping quickly through narrow passages in the soil. This kind of resemblance is technically called **convergence,** and is familiarly illustrated by the superficial likeness between whales and sharks.

CHAPTER XIII

INSECTS

The first flying animals—Birds and Insects compared—Legions of Insects—Variety of haunts and habits—General characters—Types of life-history—Some peculiarities in reproduction—Creatures of instinct—Social Insects—Useful Insects—Injurious Insects—How Insects hold their own—How Insects are kept in check—Some interrelations of Insects—Orders of Insects—Some notable Insects—The wonder of Insect-life.

THE FIRST FLYING ANIMALS.—Centipedes and millipedes and the old-fashioned claw-bearers are the descendants or modern representatives of the first air-breathing jointed-footed animals that established themselves on dry land, and many insects are also entirely terrestrial, such as most of the very simple and primitive wingless forms called bristle-tails and spring-tails. But the great majority of insects took another step—they gained wings and the power of flight. This had great advantages: it enabled them to shift their quarters quickly, to extend their range of feeding, and to evade those enemies that could not leave the ground.

A great many different kinds of animals have tried to fly, but there have been only four successes, namely the insects, the flying dragons which are extinct, the birds, and the bats. In four different ways there has been an achievement of **true flight,** which means striking and displacing the air with some sort of wings. Passage through the air by means of parachutes has been attained many different times by quite different animals, such as the so-called flying fishes, some tree-frogs, several arboreal lizards, besides mammals like swooping opossums and ' flying squirrels.' A great naturalist has said that passage through the air in more or less sustained flight has been attained by the Backboned Animals about thirty different times. But there are only four solutions of the problem of *true* flight.

In most insects the flying structures are the two pairs of wings, which are vibrated by strongly developed muscles. The flight differs from that of birds in the rapidity of the wing-strokes and in the relatively small amount of air that is displaced. It has been calculated that the number of wing-strokes per second is about 330 for the fly, 240 for the humble-bee, 190 for the hive-bee, 110 for the wasp, 28 for the dragon-fly, 9 for the butterfly. For birds, on the other hand, the number of strokes per second has been calculated at 13 for a sparrow, 9 for a wild

duck, 3–4 for a crow, 2 for a stork, and $1\frac{1}{6}$ for a pelican. Thus the number of strokes is usually far greater in insects than in birds, and for a short distance a bee can outfly a pigeon. But birds have the great advantage of soon getting up a momentum that greatly lessens the exertion required, and they are not blown about by the gusts of wind as insects are. Yet the flight of a heavy-laden honey-bee making a ' bee-line ' for the hive is worthy of high admiration.

In many cases, as in bees, the wings on each side are linked together so that they act as one; in most beetles the fore-wings are too heavy to be used in flight, but are extended at right angles to the body and clamped, so that they serve as vol-planes, the hind-wings doing the actual work; in the great order of flies (*Diptera*) there is only one pair of wings, the posterior ones being turned into rapidly vibrating ' poisers ' (or halteres) which seem to be sense-organs; in some dragon-flies there is a beautiful exhibition of ' soaring ' or ' sailing ' without wing-strokes, just as in albatross and vulture. Some wasps show a masterly power of flying tail foremost. These must serve as illustrations of the variety of flight among insects.

BIRDS AND INSECTS COMPARED.—We may think of insects as the birds of the backboneless kingdom, and they are like birds not only in the power of true flight, but in their high development of muscles, their effectively aërated bodies, their acute senses, their frequently bright colouring, and their manifold care for their offspring. When there are striking resemblances in use or function between the parts of animals not nearly related to one another, we use, as already pointed out, the word **analogous.** Thus the wings of birds and butterflies are analogous. When the resemblances are due to the fact that the unrelated animals are similarly adapted to similar conditions of life, we use the word **convergent.** Thus the rapidly moving wings of humming-birds and humming-bird hawkmoths are convergent; there is no deep-down resemblance between them. But when there is a deep resemblance in the make-up and development of structures, whether they are used in the same way or not, we use the word **homologous.** Thus the arm of man and the wing of a bird are homologous: they develop in the same way and both are fore-limbs.

We have discussed this already and it may seem a wordy matter, but it is important if we are to avoid flabby thinking. So we may say that there is much that is *analogous* between insects and birds, that there are some *convergent* resemblances, but that the two classes are so far away from one another that we cannot think of their structures as *homologous.*

LEGIONS OF INSECTS.—The number of different kinds of insects is legion. A moderate estimate of the list of the named and known *species* or kinds is quarter of a million, but many naturalists would

double this! The number of *individuals* in a swarm of locusts or in an army of ants is past telling. Insects are to be found in every corner of the earth. *Why are they so successful?* Partly because they can fly, partly because many of them are so small and elusive, partly because they have been able to utilize so many different kinds of food and so many different kinds of shelter. But perhaps the secret of their success is most of all in their power of multiplying. For many days the queen termite lays thousands of eggs at the rate of sixty per minute. A flight of locusts that passed over the Red Sea in November 1889 was said to occupy 2,000 square miles, and its weight was estimated at 42,850 millions of tons, allowing one-sixteenth of an ounce for each locust. 'A second similar, perhaps even larger, flight was seen passing in the same direction the next day.' In the first chapter we have mentioned Huxley's calculation about the multiplication of green-flies.

VARIETY OF HAUNTS AND HABITS.—(1) Many insects never touch the earth, but spend their whole life on plants and in the air. This is true of most of the gall-flies (*Cynipidae*) in the order *Hymenoptera*. (2) Many insects never leave the earth, as is necessarily the case with the primitive wingless bristle-tails and with the wingless beetles of wind-swept islands. (3) Cockchafers that fly about or rest on the branches of trees have a long larval or grub life in the soil, and so it is with many. (4) The may-flies or day-flies spend their larval life in the water, and this may last for several years, but the full-grown winged insects may have no more than one evening of aërial activity. Dragon-flies, stone-flies, alder-flies, caddis-flies, harlequin-flies, and gnats illustrate the same type of life-history, the larvae are aquatic, the adults are aërial. (5) But some insects never leave the water at all, such as the well-known water-measurer (*Hydrometra*) that runs about on the surface-film, a hazardous life for a creature that drowns if it is artificially submerged for a long time. Many different types of aquatic insects are well known (see Professor Miall's delightful *Water-Insects*); thus while many water-beetles can live submerged for hours, and spend both their adult and their larval life in the water, they are sometimes to be seen, as in the case of the great water-beetle (*Dytiscus*), taking powerful flights through the air. (6) A special place must be kept for the sea-skimmers (such as *Halobates*) that are able to live and thrive and multiply far out to sea. Some are occasionally found inshore or even on the shore, proving, if that were needed, that the original home was on land; but the usual haunt of the members of

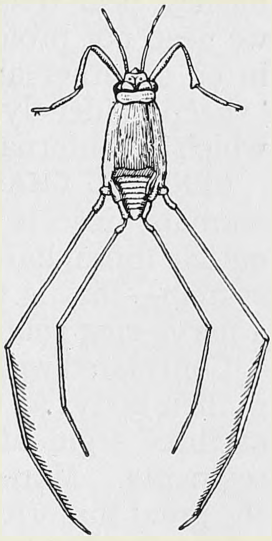


FIG. 106. *Halobates*, A SEA-SKIMMER

this remarkable family is the Open Sea. They feed on small dead animals; they dive when the sea is rough; the mother-skimmer may carry the eggs about with her. (7) Another extreme habitat is that of the so-called 'snow-fleas,' wingless spring-tails of the *Podurid* family, which are sometimes seen in countless numbers moving across a snow-field or a glacier. It is probable that they are moving from their winter quarters among the rocks in search of open water pools, on the surface of which they spend the summer. (8) Then there are hundreds of insects that live for much or the whole of their life in shelters provided by other animals or in stores of organic matter. Thus there are the little aromatic beetles which some ants and termites keep as guests or pets; there are the borers in wood, like the death-watch; there are the bookworms, the clothes-moths, the 'silver-fish,' and other household insects. (9) A huge number of insects live as parasites on plants, such as the sluggish scale-insects, often seen as flattened specks on the outside of fruits; the green-flies or *Aphides* that are pests of rose-bushes, pear-trees, bean-plants, vines, and the like. (10) Finally, for we need not prolong the survey, there are insects that live as parasites in or on other animals, as in the case of fleas and lice, the wingless 'sheep spider-fly,' and the young stages of bot-flies and warble-flies which are internal parasites in sheep and cattle respectively.

GENERAL CHARACTERS.—Like other Arthropods or jointed-footed animals, insects have segmented bodies, jointed legs, a chitinous cuticle (often hardened into armour), and the Annulate type of nervous system—that is to say, a dorsal brain, a ventral chain of ganglia, and a nerve-ring round the pharynx connecting the two.

Contrasted with Centipedes and Millepedes, Insects have three regions in their body: (*a*) the head of five to seven fused segments, (*b*) the thorax of three segments, and (*c*) the abdomen with not more than twelve segments. Moreover, they have only three pairs of walking legs, and the great majority have two pairs of wings. In front of the head there is a pair of feelers or antennae, whereas spiders, scorpions, and other *Arachnids* have none. There are three pairs of appendages in the service of the mouth, namely the mandibles, the first maxillae, and the second maxillae, which are always fused to form a lower lip or labium. But these three pairs of mouth-appendages occur in a great diversity of form, according to the kind of food. Even in the same insect they may be very different at different stages in the life-history; thus the mandibles in caterpillars are biting jaws, whereas in the butterfly or moth they are not more than vestiges. The thoracic limbs show great diversity of form, as we see when we contrast a daddy-long-legs with a mole-cricket. But there are always the three pairs, whereas spiders have four pairs. Hence insects are sometimes called **Hexapods** (i.e. 'six-footers').

As to the abdomen or posterior region of the body, probably with twelve segments originally, there is often a considerable amount of fusion or coalescence. In embryo insects there is often an indication of a number of abdominal limbs; in many larvae they are represented, thus the caterpillar has typically five pairs of unjointed abdominal 'pro-legs'; but in the adult there are in most cases no abdominal appendages. Yet this statement requires to be amplified by noticing: (1) that some primitive insects, like the bristle-tails, show two or more small abdominal limbs; (2) that some adult insects, like the cockroaches, show more or less useless vestiges or relics of abdominal limbs; and (3) that there may also be a transformation of abdominal limbs to form structures that are of real use, such as ovipositors and stings. The term *vestigial* should be kept for dwindled structures that have ceased to be of use.

Characteristic of insects, as we have said, are the wings—usually two pairs. They arise as flattened sacs, growing from the second and third segments of the thorax (the mesothorax and the metathorax). They grow out dorso-laterally, that is, from where the dorsal portion of the chitinous cuticle joins the side-pieces. As they grow out they become flattened, and they show supporting thickenings of chitin, badly called 'veins' or 'nervures,' which always follow some specific pattern. Along with the ribs of chitin there may be included air-tubes, blood-channels, and nerves. But the variety of insect wing is extraordinary—large and small, foldable and unfoldable, transparent and leathery, some covered with bristles and others with scales, while others again are naked. Spring-tails and bristle-tails illustrate **primary winglessness,** for there is no hint, even in the development, that there ever were wings in these types. But fleas and lice illustrate **secondary winglessness,** for there is evidence that these insects are descended from winged ancestors.

All insects breathe by branching **tracheae** which carry the air to every hole and corner of the body. Inside each trachea there is a spiral fibre of chitin, which helps to keep it tense, like a steel wire coiled in a spiral inside an india-rubber gas-tube. Except in a few cases, such as thoroughly sub-aquatic insects, the tracheae open by lateral openings or **stigmata,** often beautifully guarded by setae. There may be eight pairs or so of these stigmata. As in birds, the outbreathing is the active process in respiration. The cavity of the body is reduced by the contraction of special respiratory muscles, and air passes out by the stigmata. When the muscles relax and the cavity of the body expands, air passes in automatically. In short, *expiration is active, and inspiration is inactive.*

The 'blood' of insects is driven from an elongated dorsal heart by several arteries to the body, but the rest of the circulation is through

ill-defined blood-channels, which are rather lacunae than vessels. As the cavity of the body is not shut off from the blood-channels, it is not regarded as a true body-cavity or **coelom.** It is technically called a **haemocoel,** and some zoologists refuse to give the fluid the title of blood. The term **haemolymph** is used. In any case, as it is at every turn at close quarters with tracheae containing air, the capture of oxygen goes on everywhere, and the ' blood ' does not become impure in the ordinary sense. This is probably part of the secret of the insect's extraordinary activity, that its blood is being continually oxygenated. It is an interesting analogy that expiration should be the active part of respiration in types so far apart as insects and birds. In mammals like ourselves, inspiration is the active part of the process.

Most insects have compound eyes, with hundreds of facets and lenses, but many have simple eyes or **ocelli** as well. Thus a hive-bee shows three on the top of its head. In larvae, such as caterpillars, there are only simple eyes; and the same is true of lice and fleas and some of the cave-dwellers.

HEARING IN INSECTS.—When insects make sounds by energetically rubbing one part of the body against another, as is true of grasshoppers and crickets, one is inclined to infer that the sounds do not fall on deaf ears. But this is a kind of inference that one is glad to have confirmed by experimental evidence; and it has been *proved* that female grasshoppers and beetles make locomotor or other responses to the sounds made by the males. In his luminous book on *Entomology* (revised edition, 1923) Professor Folsom notes that ' male grasshoppers will answer the counterfeit chirping made with a quill and a file.' He also cites Mayer's well-known neat experiments with the male mosquito. The insect was fastened to a microscope slide and various tuning-forks were sounded. To some of these the mosquito answered back by sympathetic vibrations of his antennary hairs. This was most marked when the vibrations of the tuning-fork were five hundred and twelve per second, which corresponds approximately to the female's hum. So he doubtless hears *her.* If he adjusts his head (automatically) till the two antennae are equally stimulated, and then flies straight ahead, he is likely to find her, if he has any luck.

The higher insects, such as bees, beetles, butterflies, and two-winged flies, have a complicated life-history, with what is called **complete metamorphosis.** That is to say, a larva creeps out of the egg, and after a number of moults begins to undergo a great transformation; this is completed during a quiescent pupa state, the final result being the emergence of the winged insect.

Insects are for the most part highly-strung animals with intense muscularity and with a full sensory life. They are intensely alive, and they offer the finest illustrations of pure instinct. As in birds, there

is often a marked difference between the sexes (**sex-dimorphism**) and a highly evolved **parental care.**

Insects appeared in the Carboniferous Age, in the time of the great flowerless forests. Numerous fossil forms are known, some of which had *three* pairs of wings! As to their ancestry, there is no certain knowledge. But some of the primitive Myriapods are not far removed from the primitive wingless insects. The most difficult question is the origin of wings.

TYPES OF LIFE-HISTORY.—(*a*) In the simplest and most primitive insects—the bristle-tails (*Thysanura*) and the spring-tails (*Collembola*)—what comes out of the egg is a miniature of the adult. It grows and moults, and attains the adult size.

Similarly, the newly hatched earwigs, cockroaches, locusts, lice, green-flies, termites, and bugs are *almost* like miniatures of the adults. They may be pale in colour; they are sexually immature; and they have not got wings; but otherwise they are like their parents; and the resemblance is increased when the parents are also wingless, as is the case with some cockroaches and green-flies.

This, then, is the simplest kind of life-history, and it is called **ametabolic** (*a*, without; *metabole*, change).

(*b*) In *Cicadas* there are slight differences between the young and the adult stages, and there is a resting period before the adult characters are assumed. Even more marked is the contrast between the young and the adults in dragon-flies and may-flies, and some others. For the young are aquatic **larvae,** while the winged adults are aërial. In the larvae the tracheae are closed and some of them are spread out on 'tracheal gills' or special folds; in the adults there are open stigmata as usual. This kind of life-history is called **hemimetabolic** (*hemi*, half; *metabole*, change), that is, there is a partial metamorphosis—a larval phase but no distinct pupa.

(*c*) In all the higher insects—the *Hymenoptera* (ants, bees, wasps, saw-flies), the *Lepidoptera* (butterflies and moths), the *Diptera* (two-winged flies), the *Coleoptera* (beetles), and some others—there is a complete metamorphosis, and the life-history is called **holometabolic** (*holos*, complete; *metabole*, change). Out of the egg there comes a larva, such as a caterpillar or grub; this feeds voraciously, grows, rests, and moults, and begins to change; it sinks into a quiescent phase (the **pupa** or **chrysalid**), often sheltered in a case or cocoon; the metamorphosis is accomplished, a new style of body-architecture being adopted, and eventually there emerges the winged insect or **imago.**

There are several obvious advantages in the interpolation of a larval stage, quite different from the adult in structure and habit. (1) If the insect has to face some seasonal risk, such as the cold of winter, before

its development is completed, it is probably safer to do so as a larva, which has a less vulnerable body than the adult, and more likelihood of finding a sheltered corner. (2) The larva tends to become predominantly nutritive, accumulating reserves of food which make it practicable for the adult to devote itself more or less exclusively to reproduction. The extreme of this division of labour is seen when the adults do not and cannot eat at all, as among may-flies. (3) There is this further advantage in higher insects that all the growing takes place in the larval period, so that there is no need for moulting after the wings develop, the only exception being in the may-flies, where there is one moult after the wings are formed. This restriction of moulting to the larval period gives the higher insects an advantage over spiders and the like, especially when the larva has a somewhat compact form as in caterpillars.

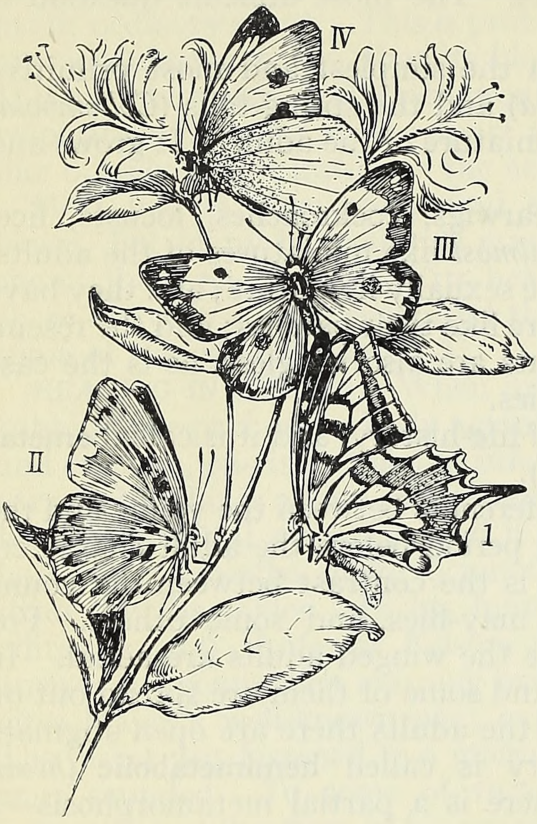


FIG. 107. SOME BRITISH BUTTERFLIES
I, Swallow-tail; II, Red Admiral; III, Pale Clouded Yellow; IV, Cabbage White.

There are many different kinds of larvae among insects, but the main contrast is between what are called the 'campodeiform' and the 'eruciform' types. A *campodeiform* larva, resembling the bristle-tail called *Campodea*, has the three regions of the body clearly defined, three pairs of strong legs, and active habits. It is well illustrated in some beetles. What are called 'hard grubs,' as in cockchafers, with hard head and limbs, but with the posterior body soft, are regarded by some entomologists as derivable from a campodeiform type.

The *eruciform* type is well illustrated by caterpillars, with a somewhat worm-like body. An ordinary caterpillar has a cylindrical body, often covered with setae, as in a 'woolly-bear' (the larva of the tiger-moth, *Arctia caia*). There is a distinct hard head, with simple eyes, small feelers, and biting mandibles. The first three segments behind the head bear jointed, clawed legs, corresponding to the legs of the adult. On the abdomen there are four or five pairs of unjointed, unclawed 'pro-legs.' The first segment of the future thorax bears a

pair of stigmata, and there are usually about eight pairs on the part of the trunk that corresponds to the future abdomen.

If the jointed legs are suppressed, the larva is called a 'soft grub,' as in bees; if the head is also much reduced, it is called a **maggot,** as in blue-bottles, this degraded form being plainly suited for developing in the midst of a mass of foodstuff, such as dead flesh.

It sometimes happens that one and the same insect shows both campodeiform and eruciform larvae. Thus, as Professor Carpenter notes in his *Biology of Insects* (1928), 'the young of many oil and blister beetles are hatched from the egg as tiny, active, armoured campodeiform larvae which seek to attach themselves to the body of a bee, and if successful, are carried to the nest, where, after the first moult, they become changed to soft-coated grubs feeding on the stored honey.' This illustrates what is characteristic of larvae, that they are adapted to particular conditions of life. This is also well shown by many aquatic larvae, such as those of mosquitoes.

In the more old-fashioned insects, such as cockroaches and locusts, there is the usual gradual development of the adult structures. But in all the higher insects there is a **metamorphosis.** In the course of the larval period there is the beginning of a new kind of architecture, and this is completed during the pupation. In this metamorphosis, which is one of the most remarkable processes in the world, there are two kinds of change. On the one hand, there is a breaking-down of the larval structures, including muscles and air-tubes, and part of the food-canal. This scrapping of the old edifice is called **histolysis** (*histos,* tissue; *lysis,* dissolving), and it is sometimes, though by no means always, aided by wandering amoeboid cells called **phagocytes** (see INDEX), which play many rôles in animal life. They are usually active in the metamorphosis of flies. But while the scrapping is going on there is also rebuilding, and in this **histogenesis** (*histos,* tissue; *genesis,* becoming) an important part is taken by folds or disks which grow in from the larval skin, and form the foundations of the new organs. Thus even in the very young caterpillar there are two pairs of minute ingrowths which form the foundations of the future wings. The ingrowing disks are like nests of embryonic cells which initiate a new kind of development, and one of the difficulties is that new hereditary characters and impulses, which were previously unexpressed, begin to assert themselves. In the famous North American seventeen years' locust (*Cicada septendecim*) the larvae live underground for nearly seventeen years, and then give rise to noisy winged insects; and it is striking that a great part of the inheritance should remain unexpressed for so long a time. But the marvel is the same whether the larval life is short or long. The nests of cells which start new organs are

called **imaginal disks,** not a very intelligible name till we recall that 'imago' is the technical title of the winged or fully formed insect. An imaginal disk is a cluster of ingrown cells which have returned to embryonic many-sidedness, and proceed to form structures which are peculiar to the imago.

If we open the barrel-shaped cocoon or pupa-case of some of the flies, we find inside what looks to the naked eye a creamy mass. This is an instance of very drastic histogenesis, whereas that seen in the caterpillar-to-butterfly change is very gradual. So in the replacement of a building in a city we may see the entire scrapping of the old structure and a rapid rebuilding; or we may see the pulling down of one corner and the building up of another, all in a piecemeal, gradual fashion.

SOME PECULIARITIES IN REPRODUCTION.—Many insects are very prolific. From a single mother *Aphis* or green-fly there would arise in a few summer months a vast progeny of hundreds of millions, provided that all the members of the successive generations flourished and multiplied. Fortunately, nothing like this ever happens. The queen-termite lays tens of thousands of eggs at the rate of sixty per minute, hour after hour. She is probably the most prolific of all animals.

It is impossible to understand the life-history of such insects as ants and hive-bees unless we recognize that a store of sperms received by the female from the male, and retained in a special receptacle, may be used for a long time—even for several years—to fertilize the eggs as they are laid. A queen-bee may, if she is allowed, continue to lay fertilized eggs for two or three years after her nuptial flight, during which she was inseminated by a single drone. The record for ants is much longer, and it must be carefully noted that it is not a question of laying eggs, but of laying *fertilized* eggs.

Another reproductive peculiarity is the occasional occurrence of virgin birth or **parthenogenesis.** That is to say, eggs may be launched on the voyage of development without being fertilized. All through the summer months the green-flies or Aphids are females, no males occurring till there is a hint of the cold and scarcity of autumn. In the artificial summer of a greenhouse this parthenogenesis may continue for several years. In some of the gall-flies there is an alternation of parthenogenetic and ordinary sexual reproduction. Sometimes the parthenogenesis is what is called 'voluntary'; thus it depends on the pose of the queen-bee's body whether the egg she lays in a particular cell is fertilized or not. If it is fertilized, it develops into a queen or a worker (an arrested female), the difference depending on the nutrition of the larvae. But if it is not fertilized, the egg develops into a male or drone. Thus the drone-bee (wasp also, or ant) has a

mother, but no father. But plainly enough the drone has a grandfather, the queen's father.

Another peculiarity about the green-flies or Aphids is that the females produce almost fully formed progeny, which are ready in a short time to do the same in their turn. In other words, instead of being oviparous (egg-laying), like most insects, the summer green-flies are **viviparous.** The young ones are hatched from the eggs while still within the body of their mother. This viviparous birth occurs in some beetles, cockroaches, and flies, and in a few other cases. It may be recalled that it is characteristic of the primitive claw-bearers, such as *Peripatus* (p. 235). It is of great advantage in enabling the offspring to start at once on the business of life.

CREATURES OF INSTINCT.—The climax of instinctive behaviour is seen in ants, bees, and wasps. And what is instinctive behaviour? The term is no longer used in a loose way, it has a precise meaning, though we may not altogether understand its secret. The characteristics of instinctive behaviour are the following: (1) It is due to an inborn or hereditary capacity, and does not require to be *learned*, though it may be improved by practice. A hive-bee, never out of the hive before, flies to a rather difficult flower, such as heather or white clover, and deals with it deftly, as if it had been gathering nectar all its life. (2) Instinctive behaviour is a kind of routine that is shared equally by all members of the species of the same sex. It is an inborn capacity for doing apparently clever things, and does not vary, as intelligence does, from individual to individual. (3) Instinctive behaviour is very stereotyped. It is connected with particular things and situations, which are of critical moment in the animal's life; and while this gives the performance great readiness—requiring no apprenticeship—it involves the great disadvantage that even a slight change in detail may confuse the creature hopelessly. If the first member of a string of procession-caterpillars, in Indian file, is carefully guided so that his head is brought to touch the hind end of the last in the file, then the creatures go on for days circumambulating in a futile circle. There is no evidence that instinctive animals in their instinctive behaviour have any clear appreciation of the situation, as is the case with intelligent animals; yet a predominantly instinctive creature may also be occasionally intelligent, just as a predominantly intelligent animal may be occasionally instinctive. (4) On its physiological side instinctive behaviour is comparable to a chain of reflex actions, one giving the cue to the next in succession; but it is probable that there is also a subjective or mental side, for there is much to lead one to believe that instinctive behaviour is *suffused with awareness*—more or less vivid, and *backed with endeavour.* In intelligent behaviour, such as some insects may occasionally exhibit, there is always some understanding of the situation, some appreciation

of the relations of things, some learning and deliberate controlling. On the inner or mental side there is some judgment or perceptual inference—playing with mental images. When there is *conceptual* inference, experimenting with general ideas, as occasionally in man, it is **reason.**

SOCIAL INSECTS.—The greatest authority on insect societies is Professor W. M. Wheeler of Harvard, who has written a fine book, *Social Life among the Insects* (1923). In that book he shows that to all appearance societies have arisen twenty-four different times in this one class of animals. That is to say, there are insect societies in twenty-four different groups that are not nearly related to one another. Thus wasps are not nearly related to bees, nor true ants to white ants. Time after time in the course of the long-drawn-out history of insects there must have been a fresh formation of societies.

We mean by a society something more than a crowd or a mob; thus no one would say that a vast multitude of mosquitoes was in any way a society. The distinctive feature is that a society has some corporate life, some permanent power of acting as a unity. A society always implies team-work, many individuals working in harmony with others. When the rule of life is ' each for himself,' as is usual, for instance, among beasts of prey, there is no approach to a society. We shall return to this point, but we must be clear at the outset that an animal society, like an ant-hill or bee-hive, always means the habit of team-work. This may take simple or very elaborate forms; the society may be small or large; it may last for a season only or from year to year. Many grades of society are illustrated by insects; and the chief groups that include social types are: Bees, Wasps, White Ants or Termites, and Beetles. To these must be added some of the earwigs, and a few rare insects called *Embiidae*, which live in silken webs under stones and bark. The female of a large Himalayan species, *Embia major*, nearly an inch long, shows great solicitude for her eggs and larvae.

SOCIAL BEETLES.—Simple forms of social life are known in several unrelated groups of beetles, such as the scarabees and dung-beetles. There is no division of labour in the little communities, but there is marked parental care, in which the males sometimes take part. Some of these simple communities grow a food-fungus called ambrosia. The Tachygalia beetles, e.g. *Coccidotrophus*, live in the hollow leaf-stalks of certain (*Tachygalia*) trees in British Guiana. They have as habitual companions small ' mealy-bugs ' (*Coccidae*) which they milk or tap for the sake of a discharge of sugar and water, derived originally from the sap of the tree. Another kind, *Xyleborus perforans*, is known in the Tropics as ' tippling Tommy,' for it has a strong liking for boring in the staves of barrels containing beer, wine, or rum.

Social Life of Ants

Professor Forel's *Social World of the Ants* tells us what a first-class observer knew about the social organization of the little people, their customs and conventions, their wars and slave-making raids, their domestic animals and pets, their cultivations and stores, their tyrannous instincts and their occasional exhibitions of plastic intelligence. But the question to which we wish to give prominence here is this: What is the biggest difference between human and myrmicine societies? No doubt there is in human society a very important external registration of tradition, which is only incipient in the ant-hill; no doubt man is one species, while ants are many; no doubt the ant-community includes a special reproductive caste and depends for its sustenance on a vast proletariat of arrested females or ' workers '; but the fundamental difference is *mental*.

In our estimate of the mental aspect of the ways of ants we must first of all remember that the little creatures are very well endowed with senses. They have touch-bristles (or *tactile setae*) at strategic points on their angular bodies; they have a sense of balance or equilibrium; they react to slight changes of temperature. They have taste ' receptors ' on their mouth-parts and smell ' receptors ' at the tips of their feelers. Their compound eyes are particularly quick to detect movements; and they can see the ultra-violet rays to which we are normally blind. On the other hand, ants appear to have no colour-sense, though they are able to distinguish light and shade. They are sensitive to vibrations, but it is uncertain whether they can detect sound-waves as such. Yet some of them make tiny instrumental sounds or **stridulations,** in one species loud enough to be audible to man. They cannot have much sense of pain, for an ant will eat honey greedily though it has just lost the posterior half of its body. Numerous very careful experiments seem to justify the statement that ants have no sense of direction, for their powers of ' homing ' are the outcome of topographical experience, in the course of which they take advantage of differences in light, temperature, odour, and so forth.

Of essential importance in myrmeco-sociology is the ' antennary language ' by which ants communicate with one another. According to Father Wasmann, there is a touch-vocabulary. The antennary tap or stroke may mean: ' Come to work,' ' Give me food from your honey-sac,' ' Let us be off,' ' I have found a treasure,' ' There is a danger,' ' Let us fight.' There seems to be a special signal when a slave-making raid is in prospect. By friendly antennary caresses, frequently repeated, an ant may seek to calm the excitement of a neighbour. This differentiation of tactile signalling must be of great importance in communal activities.

Kipling has given us a lively report of the conversation of the locomotive engines in a railway shed, and some naturalists are strangely of opinion that ants are little more than very complicated miniature mechanisms which thrill to one another's touch. But one of the facts that contradict this extreme mechanistic theory is that ants betray no small degree of **feeling.** They may be excited or depressed, playful or discouraged, pleased or angry. Their touch-language varies with their 'state of mind,' for they strike rapidly or at longer intervals, forcibly or caressingly, with their antennae or with their head; and the part of their neighbour's body that they tap is different in different circumstances. We infer the feelings of the deaf and dumb among ourselves, and we must do the same for the ants. It is a fact of observation that a particular feeling may spread from one ant to another in the community; they are not automata.

In some cases it seems as if they conveyed definite information to one another, but we must walk warily here, remembering the long-standing acceptance of the mistaken view that a worker-bee tells her fellows of the nectar-treasure she has found, or even guides them to the place.

Sir John Lubbock (Lord Avebury) often made the experiment of pinning a dead ant to a piece of cork and leaving it at some distance from the rest, to be discovered by a rover. Obedient to instinct and custom the roving ant tried to carry away the corpse, but as this was impossible it went off home and soon returned with several fellow-workers. They cut up the pinned-down corpse and carried it away piecemeal.

Even more striking is one of Father Wasmann's experiments. In the refuse-chamber of an artificial nest of the red ant he placed some cocoons of two other species, inserting them at a time when no ants were present. The cocoons remained unnoticed for an hour and a half. The experimenter then took a single red ant and placed her in the refuse-chamber near the cocoons. After a moment she ran to the upper nest, crossed it without stopping, and passed through the ante-room into the main nest. Scarcely ten seconds had elapsed before a horde of red ants rushed out of the main nest, through the ante-room and the upper nest, and, after hesitating for a few seconds only, betook themselves to the refuse-chamber, where they began to transport the cocoons to the main nest, continuing to do so all the afternoon.

Auguste Forel studied ants all his long life, and he also had the advantage of professional experience as a specialist on mental diseases. He was familiar with the many pitfalls that imperil the student of animal behaviour, and this gives peculiar value to his general conclusions. In a human society a large percentage of everyday actions may be said to be determined by what has been *learned* by the in-

dividual—by thinking, reading, observing, or simply profiting by experience. Forel puts this down at an average of 60 per cent. The rest of human activity is determined by what is *inborn*—that is by instincts, predispositions, prejudices, passions, the Primary Unconscious, and unreflecting acquiescence in folk-ways. This Forel estimates, as we have said, at 40 per cent. How does the ant's behaviour compare with man's, according to this expert's valuation?

Forel thinks that the inborn, hereditary, or instinctive counts for 95 per cent of the ant's activities. To this must be added 4 per cent for emotional promptings and for habituations engendered in the communal life—what Forel calls 'secondary automatisms.' That leaves only 1 per cent for *reflection*, which can modify the ant's actions according to circumstances and special cases. This brings out the immense gulf between the predominantly instinctive societies of ants and the predominantly intelligent and rational societies of men. Little wonder that we can hardly breathe in the atmosphere of the formicary, where instinct reaches its climax.

What evidence is forthcoming in regard to the 1 per cent of reflective behaviour in ants—'a trifling fraction,' Forel says, 'which can only be perceived by close attention and much perseverance on our part'? Forel found his evidence of flashes of intelligence in cases where the routine of instinctive behaviour is departed from. When ants and their cocoons are turned out of a bag in an unfamiliar place there is a hurry-scurry for safety. A leader discovers what looks like a refuge. 'She turns quickly to her companions and seizes one of them, or a cocoon, to take it into shelter. But she has had no time for thorough orientation. When she has a burden she sometimes loses her bearings. She then lays down her burden for a moment and tries to find the way by means of her antennae and her sight.' When she has got her bearings again she picks up the cocoon, or, it may be, a companion who folds up its legs and allows itself to be carried. When the shelter is reached and approved of, the companion sets off to bring in another, and so forth. But if a better refuge should be discovered there is a speedy flitting.

Wasmann trained an ant so thoroughly that she would come to eat off his finger. Turner trained several cocoon-carrying ants to fall off a minute platform on their way back to the nest; when he put them back on the platform with a brush they repeated the performance several times. Even more striking was Turner's success in teaching an ant to use a small movable wooden bridge, made in sections, to pass from a platform to an island nest! But the achievements of trained ants are less convincing than the plasticity exhibited when something occurs to disturb the usually effective instinctive routine. It is interesting to notice that the capacity for *plastic learning* varies greatly

from species to species, the red ant being an easy first in Switzerland. There is also food for reflection in the fact that the males are stupid compared with the workers—' arrested females ' though these be.

ARCHITECTURE AMONG ANTS.—Hive-bees make their honeycomb with perfect artifice; wasps hang a paper house of many stories from the branch of a gooseberry bush; termites build an elaborate edifice, sometimes ten feet high and with many rooms and passages—but ants cannot compare with these. For ants' nests are apt to be rough-and-ready; their architecture is irregular and inconstant. Yet its variety and plasticity command admiration.

The ants' nest may be a mine excavated in the earth by multitudes of tiny jaws. The mouth of the shaft may be hidden, or, when the species has a strong footing, it may be very conspicuous. Sometimes it is surmounted by a heap like the crater of a volcano, or by a turret a few inches high, built of cemented earth; and in other cases the turret is replaced by an elegant vase like the trumpet of a flower. Forel describes an extraordinary case, which he does not profess to understand, where an Indian ant surrounds its vase-like turret with six to eight circular ramparts, the outermost nearly a foot in diameter. In some cases the entrance to the shaft is covered by an earthen dome, or sometimes by a flat roof, which is fastened to the stems of stout grasses. This kind of masonry is only possible when there is rain to moisten the soil. There are all sorts of gradations among the domed nests, some very transient, like men's huts in China, and others very stable; some with an empty interior, and others with rooms and passages communicating with the underground part of the home.

The use of the dome is to conserve the warmth, and in some cases the upper part, which is most crowded, is bent towards the morning sun. Of course it is simpler to utilize a stone with a suitable cavity beneath it, and that is often done, though rarely in tropical countries, where an under-stone home would become unbearably hot.

In steppe country and deserts the ants' home is often excavated in the sand, and may be very extensive. Forel spent hours in studying one in Algiers, and found half a dozen ' craters ' at intervals of three to ten yards, all connected by an underground passage which ran at a depth of about five feet. But that did not nearly exhaust the underground home, which may have extended over fifty to one hundred square yards. To each crater there corresponded an underground granary; but it was all one vast nest, inhabited by one community. The grains of sand are carried out in the jaws or entangled in special hairs about the mouth.

Many of the ants that nest beneath the ground are also found under the bark of old trees or in a decaying stump; and they may use the powdery fragments of wood to build galleries and chambers. Some-

times they have arboreal stables in which they keep their 'cows'—the *Aphides*—during the winter. A step further brings us to those ants that make elaborate tunnels in the hard wood of a tree. There is a little doorway in the bark, a straight passage through the sap-wood, which they do not injure, and then a labyrinth of passages, up and down and crosswise. The tunnels may become so extensive that the tree gives way in a storm, and the same may happen to the wooden support of a bridge or a hut. These tree-boring ants approach the termites in their industry.

Here may be included those ants that utilize cavities already existing in trees and other plants. Thus some acacias have a body-guard of protective ants inside their hollow thorns; the *Imbauba* tree holds an army inside its hollow stem; and the tuber of the famous *Myrmecodia* has an internal maze which looks just as if it had been made for ants to inhabit. In the last case the system of passages and cavities, reminding one of a sponge, turns out to be an absorbing organ developed by the plant itself; but it is tenanted by ants all the same.

Some very interesting ants' nests are made out of paper, after the wasps' fashion. The papery material seems to be produced from wood-dust and the juice of the mouth. Occasionally there are fibres and minute parts of plants in addition to the particles of crumbling wood; and a kind of ant that habitually makes a papery nest will make one of sand-grains cemented together if it cannot get its usual materials. Inside the nest there is often a velvety growth of a black mould which the ants are fond of eating. Paper nests may hang down for two feet from the branch of a tree, but they are usually nearer six inches. Forel describes big ones from the Brazilian forest that hang down like stalactites, or, when they are covered with pendent threads, like the beard of some great giant among the trees.

There are a few ants that utilize in the construction of their nest the fine sticky threads which ooze from the mouths of their larvae. The worker takes a grub in its mouth and uses it like a gum-bottle, binding leaves together. In some nests a delicate web is formed as the basis, and to this there are attached tiny pieces of leaf and lichen, and even the minute feathers of a bird. There is an ants' nest in Batavia that consists of a single flattened chamber, constructed at the fork of a branch; it is so well disguised that only an expert eye can distinguish it from an extension of the lichen. This is perfect camouflage.

There are a few ants that nest in holes in the rock and have a domicile that may be called indestructible. What a contrast between that and the state of affairs among the nomad ants that are always on the move! In the course of a night, Forel tells us, the whole horde may shift its camp. They utilize the nests of other ants, whom they

evict, or a hollow tree, or rotting wood; but inside their temporary shelter there are always found living balls of ants hanging on to one another by their clenched jaws, and inside the ball is the brood! Such a living cradle may be floated across a streamlet without its components losing their grip; and another almost incredible story is the making of a living bridge across which the raiders pass. It has been recently recorded of the Argentine ant that has done so much damage as an intruder in Madeira that it will build a bridge to get across sticky fly-paper or any similar morass.

In pine forests in Britain and in the States there are often enormous domelike nests—the familiar ant-hills. We measured one which was three feet high and six feet in circumference; but there must be many a great deal larger. When we housebreak a little, and peer in, we see that the ant-hill is mainly built of the withered twin needles of the pine; but there are many other contributions—pieces of fibre, small twigs, short bits of grass-stem, fragments of resin, and even small snail shells. Below the loose labyrinth of leaves there is a substantial construction of roughly built earthwork with rooms and galleries, but the proportion between the loose and the substantial part of the ant-hill varies with the species. As we disturb the routine of the ant-hill we see the hurry-scurry of the worker-ants, many of them with a pupa in their mouth, carrying it away to possible safety. The instinct that is dominant is not self-preservation, but children first. These white pupae, popularly and badly called ' ants' eggs,' are, of course, the chrysalid stage between the grub (or larva) and the fully formed adult (or imago).

In these great ant-hills we have to do with several big families living together in a friendly community. There are often three or four nests in the one hill, but there may be thirty; so that here we are face to face with the transition from a family to a society. The big ant-hill below the pine trees is a hamlet.

THE TRACKING INSTINCT IN AN ANT.—There is in Florida and in the Tortugas a small reddish-brown ant called *Monomorium destructor*, really of East Indian origin. It well deserves its name of *destructor*, for it is a great pest in wooden buildings, making its nests in the chinks and crevices. Dr. Alfred Goldsworthy Mayor writes: ' So voracious are these insects that we are obliged to swing our beds from the rafters and to paint the ropes with a solution of corrosive sublimate, while all the tables must have tape soaked in corrosive sublimate wrapped round their legs if ants are to be excluded. These pests have the habit of biting out small pieces of skin, and I have seen them kill within twenty-four hours rats which were confined in cages.'

Experiments were made in order to discover something reliable in regard to the way in which these ants *track their food*. Recently

killed house-flies were impaled on pins which were thrust into the wooden floor in the way of a wandering ant. If the ant's course brings it nearer the booty than a quarter of an inch, it suddenly turns and inspects its find, spending half a minute or more crawling over the dead flies and stroking them with its antennae. It soon leaves them, however, without carrying off a fragment, but instead of moving in an erratic way, it goes on a fairly straight path towards some crevice in the floor. Out of this there soon issues an excited swarm of its nest-mates, which proceed towards the flies on an approximately straight path, not necessarily identical with that taken by the 'finder-ant' that brought the news. In many cases the path of the return swarm is not quite right, and thus the ants will pass to one side or other of the booty; but, curiously enough, when the right *distance* has been traversed, and the ants are missing the flies, the swarm breaks up into scouting parties which wander in random fashion in all directions, describing what are technically called 'Turner's curves.' The file of ants seems to gauge the *distance* with great success, for Dr. Mayor never saw them miss it by more than two inches in a journey of eight feet. But they often miss the *direction* by as much as four inches to one side or other of the flies. Many of the scouts find nothing, of course, but others are successful, and within a few minutes a swarm-path is established between the nest and the flies.

If a circle of corrosive sublimate solution be drawn around the 'finder-ant' when it is inspecting the booty, the finder stops at the barrier on its home journey, and suddenly goes straight back to the dead fly. It starts again and stops again, and repeats the performance several times. Finally, it goes through the moat of corrosive sublimate and reaches home. But when it meets its fellows and rubs antennae with them, they are not excited, and no swarm comes back to the fly. Crossing the chemical has spoilt the news.

If, when the swarm has started, a ring of corrosive sublimate be drawn around the fly, the ants coming from the nest are at once arrested when they reach the moisture. A block occurs, but in about a minute nearly every ant between the outside of the ring and the nest is seen to be returning home. If a 'finder-ant' is lifted and brushed, it is incapable of conducting a return swarm to the fly. If a finder is injured, its nest-mates do not attend to its news. When the finder rubs antennae with its fellows, intense excitement normally follows, and this spreads by contact. They crowd around the finder, and the probability is that the normal function of a finder-ant is personally to conduct its nest-mates back to the food it has discovered. With hive-bees, however, there is no personal conducting; the explorers take advantage of an olfactory cue that the finder affords.

ANTS GUIDED BY A STAR.—For many years people believed what

they liked in regard to the ' homing ' power exhibited by various kinds of animals. Some said ' instinct,' others ' a sense of direction,' others ' trial and error,' and so forth. But many patient and ingenious experiments have been made, whence some certainties are emerging. Thus it looks as if the ' homing ' of ants and bees was different from that of migratory birds, inasmuch as the insects serve an apprenticeship in the vicinity of their home, and learn in their orientation to take advantage of external hints. It becomes habitual, no doubt, to use these diverse ' guide-posts,' but the utilization has to be *learned*. Sometimes the stimuli are near at hand, such as the odoriferous foot-prints of previous journeys or the slope of the ground; sometimes the stimuli are at a distance, such as the position of the sun in relation to the nest. Dr. F. Santschi has made many experiments with pale big-eyed ants that work at night on the Tunisian desert and seem to ' find their way home ' with the help of the moon. Not that they use the moon as a lantern to enable them to see their way, it is rather that they set their course on their outgoing by observing the relation of the moon to the nest. When a cloud forms a curtain over the moon the travellers go astray—they scatter; when the cloud passes they orientate themselves afresh, and rightly. But there are many moonless nights on which the ants find their way about if there is a clear sky with stars; and Dr. Santschi has come, after much deliberation, to the conclusion that the ants use the stars in their orientation. His records do not betray any twinkle in his eye. One of the neat experiments was to surround the travellers with a cylindrical screen which shut off everything except the patch of sky above. That seemed to afford sufficient guidance, and it is difficult to brush aside the suggestion that the stars are of use to certain ants as they were to ancient mariners. It must be remembered that man's eye becomes very much more sensitive after he has been shut up for a while in a dark room, and the same may be true of these nocturnal ants. Moreover, ants are sensitive to **ultra-violet rays** that man does not normally perceive. And just as stars can be seen in the daytime if we go down a sufficiently deep well (as Aristotle said), so Dr. Santschi maintains that the eyes of ants and most other insects may give their possessors a similar vision. He alludes to the fact that the **compound eye** is built up of a large number of ' eye-elements ' or *ommatidia*, each including cornea, lens, and retinula, and each wrapped up in a dense mantle of black pigment—corresponding to the sides of the well.

THE SO-CALLED AGRICULTURAL ANT.—Every one has heard of the ' Agricultural Ant of Texas,' originally described by Lincecum in 1862, and the subject of a book by McCook. The story Lincecum launched was that the agricultural ant intentionally and exclusively cultivates a kind of grass, known as *Aristida oligantha*, all round the

domed nest. It was said that the ant cuts off all other plants within the circle of the little field. Thus this ant, which bears the euphonious name *Pogonomyrmex mollefaciens*, was the first farmer. This was a pleasant story, but it suffered from the defect of not being true. There is no doubt that the ant makes a clearing around its domed nest, the object being to secure a warmed dry area where the young may be sunned and the seeds dried. There is no doubt that the Texas ant, like many another, gathers seeds and stores them. Among these seeds are those of the grass Aristida, which are afterwards used as food by the workers, or broken and salivated and given to the young ones. But the grass seeds frequently sprout in the ant-granaries, which may become stuffed with young plants. 'The ants may then be seen removing the seedlings which have sprouted too far to be fit for food, and throwing them on the refuse heap which is always at the periphery of the crater or cleared circle.' Here they sometimes take root along with other plants that have been rejected. But this only occurs in a minority of cases. The true story is interesting, but it is not so extraordinary as Lincecum's legend, which even the Texas schoolboy now hails as a good joke. It may be noticed that *Pogonomyrmex mollefaciens* has a bite ferocious for the size of the insect, and was used by the ancient Mexicans in torturing their prisoners. Ants differ in their treatment of seeds, but some of them bite off the protruding tip when sprouting begins, and then dry them dead in the sun. Others allow the sprouting to continue until the firm seed-envelope is burst, and then dry them thoroughly.

THE ARGENTINE ANT IN MADEIRA.—One of the clearest of Natural History lessons is to beware of strangers of dubious character. For the intrusion of an insurgent newcomer—a new weed, a new insect—always means the risk of a big rent in the web of life. A good instance is the deplorable story of the invasion of Madeira by the Argentine ant (*Iridomyrmex humilis*). It has established its destructive colonies up to 2,500 feet above sea-level; it has completely suppressed competing species; it has ruined coffee cultivation and seriously affected the crops of sugar cane, bananas, and sweet potatoes; it has almost destroyed every fruit tree that supports the *Coccus* insects and *Aphides* (green-fly), in which it is particularly interested; it has invaded every house and attacked every kind of stored food; poultry, young birds, and bees are defenceless before it. It seems to be as formidable an agent of destruction as the Colorado beetle or the cotton-boll weevil. The trouble is that there is in Madeira no winter weather to check the invasion, that enemies are few (though some spiders do their best), and that the intruders are desperately ingenious. Banding trees with rags soaked in corrosive sublimate is very effective, but the method is limited in applicability. What is to be made of creatures that build bridges to

reach the corpses of flies on sticky fly-paper? Moreover, the ants in question seem to be remarkable in their communal harmony; they do not quarrel among themselves—a most unfortunate virtue from the Madeira farmers' point of view. But the story is one for tears and for our warning.

HOW QUICKLY DOES AN ANT RUN?—Socrates is said to have inquired into the distance that a flea could jump, so it is not trivial to ask how quickly an ant can run. Mr. Shapley has made very careful observation on a Californian ant common on Mount Wilson which works ceaselessly day and night. The average live weight of the larger workers is about five-hundredths of a grain (140,000 to a pound), and that of the smaller type half as much. So the little creatures have not much to carry! At low temperatures the speed is 0·44 centimetre a second (10 inches a minute); when the temperature rises to 30° C. the speed is 6·6 centimetres a second (150 inches a minute). The interesting point is that the speed increases in almost precise proportion to the temperature, between certain limits.

POISON OF ANTS.—When one disturbs a large ant-hill in the wood there is a distinct scent. That is apparently due to formic acid, which is the commonest poison in ants. It has a toxic and also a corrosive action. But there are many poisonous ants without any formic acid; and the nature of their venom is still uncertain. It may be of an albuminoid nature. There are some ants which do not sting at all, doing nothing but bite. The bite may be painful enough, but it is not in itself poisonous.

When true ants attack the unrelated white ants or termites they sometimes get an unpleasant surprise. For the soldiers of some kinds of termites are able to squirt a glutinous fluid in the face of small creatures like ants who trouble them, and the douche is fatal. The fluid is contained in a bilobed gland at the sides of the head posteriorly, and it can be squirted out by a median opening at the end of the beak. The squirting is due to the contraction of muscles in the lateral regions of the head. As to the nature of the fluid, it is colourless, viscous, and resinous, with an aromatic odour like cedar oil. When an ant gets some of this in its face it rushes about distractedly, trying in vain to rub it off, and then succumbs. There seems no end to the subtleties of thrust and parry in Animate Nature.

Bees

LIFE-HISTORY OF HUMBLE-BEE. — The only humble-bees that are alive in winter in North Temperate countries are the young queens, born in the previous summer. They lie in a sheltered nook in a mossy bank or at the base of a tree; in a peculiar position with the

legs drawn up towards the head, recalling the position of the young in the pupa state before they got their wings. Some of them have been lying low for eight or nine months—from July, it may be, till April. In his charming book *The Humble Bee* (1912) Mr. Sladen notes that the site chosen for the winter rest has usually a northern aspect, for 'the sun never shines on northern banks with sufficient strength to warm the ground, so that the queens do not run the risk of being awakened on a sunny day too early in spring.' It would be very unprofitable to be wakened before there were any flowers from which to get food. It seems that the winter resting-place is not chosen in a hurry, for the bee will change her lodgings if they are not comfortable. The most important point is that the site should be sheltered and dry; and dryness means drainage. Before betaking herself to the winter quarters the young queen has a large meal, and the energy derived from this will keep her going for a while before torpor sets in. But when she has quite settled down and become lethargic, there is no stirring till spring. The huddling-up that we referred to probably reduces the surface of the body that is exposed to the cold. What the state should be called we do not know; it is not sleep, it is not hibernation, it is a state of **suspended animation.** Was ever 'sleep' so near to death as the lethargy of the wintering queen? In the ordinary sleep of higher animals and man the heart is beating as usual, the breathing movements continue, digestion goes on and also excretion, the muscles produce heat, and so forth; but there is very little sign of life in the wintering queens of the humble-bees. They are not asleep. In true **hibernation,** which is confined to certain mammals, like hedgehog and dormouse, the body is in a very peculiar state: thus the heart beats very feebly, the breathing movements are scarcely perceptible, there is no digestion going on, excretion has stopped, and so forth; but the queen-bees are not in this state. Their body is like a watch that has ceased to go though it has not run down. Or is it like a glacier that is flowing, but flowing so slowly that we find it difficult to demonstrate the fact? We linger over this puzzle, for it is one of the wonders of life that it can come so near to death and yet evade it after all.

There are many kinds of humble-bee, but two of the first to 'awaken' in spring in Britain are the large earth humble-bee (*Bombus terrestris*), velvety black with two bands of deep yellow and with a tawny tail, often wintering under a tree; and the smaller early-nesting humble-bee (*Bombus pratorum*), which is also black and yellow-banded, but red behind, often wintering in a mossy bank.

No doubt there is some established routine or rhythm in the body of the comatose queen which leads to renewed activity at the fit and proper time, just as a fire which has been smouldering for a long time

may burst suddenly into flame. But the sunshine of spring pulls the trigger, so to speak. Sometimes, however, there is a want of time-keeping between the internal rhythm and the external punctuation, and the queen may awaken long before she is ready to be a mother, or long before the early flowers afford a sufficient supply of nectar and pollen.

In the large earth humble-bee in particular, what first happens after reawakening is refreshment. The queen attends first of all to herself. There are recuperative days, perhaps the only approach to a holiday in the queen's life, when she searches for early flowers, such as willow-catkins, peach-blossom, and red dead-nettle. On the golf-links we often see her in April visiting the minute dwarf willows, whose tiny catkins are more than half hidden in the turf. The early-nesting humble-bee is very fond of the beautiful blossoms of the red-flowering currant, which are available very early, as every one knows. But if the air grows chilly in the afternoons, the queens return again and again to their winter quarters, and Mr. Sladen tells us that they may relapse into semi-torpor, remaining in this condition until favourable temperature again rouses them to activity. As the weather improves, the periods of activity become longer and longer, and the now vigorous young queen begins to search for a suitable site for a nest in which to lay the eggs.

The nest of the large earth humble-bee is usually underneath the ground and approached by a short tunnel. In many cases it is the deserted nest of a field-vole with convenient fragments of grass ready bitten. Here is one of the **linkages** so common in Animate Nature; the field-vole is an enemy of the humble-bee and often burgles the nest, devouring the plump grubs; yet the humble-bee may make use of the vole's nest as the site for her own. The early-nesting humble-bee sometimes utilizes a bird's nest at a considerable height off the ground.

In all cases the queen's first business is to make sure of the lie of the land, so that she may be able to find her way home after a journey. Thus she issues from the chosen site, and hovers around, keeping her eyes homewards. She takes her bearings carefully and does not venture far until she has gone out and in several times.

The next step is to make the nest tidy and comfortable. It is often no bigger than a walnut—about an inch in diameter and about five-eighths of an inch from floor to roof. In the middle of the floor the queen places a lump of pollen-paste, and on this she builds a circular wall of wax. Within the cell thus formed she lays her first batch of eggs, and she covers them by drawing the margins of the waxen wall together. It may here be noted that the queen is, so to speak, a young widow; she was mated with a drone that died at the end of the previous

summer; she fertilizes her eggs from a store of sperms which she received from the male on that occasion. Having laid the eggs and covered them, she proceeds to brood, and she continues this for about three weeks, first sheltering and warming the eggs, then the hatched grubs, and finally the pupae. An interesting detail is that before brooding she makes a conveniently situated honey-pot, filled brimful with nectar. She can sip at this store during the cold night, or when there is bad weather, and she keeps it replenished by making brief foraging excursions. We may almost call it 'the widow's cruse,' for it is always being used without becoming exhausted, and the queen-bee is a widow.

When the first workers emerge from their pupa-cases they get a meal from the honey-pot, and are soon able to venture into the open world, whereupon the habits of the queen undergo a marked change. She becomes a stay-at-home mother, and delegates all but actual maternity to her worker daughters. They collect the food and they also nurse the successive broods. In some cases the workers lay eggs, which develop, without being fertilized, into drones. But most of the drones are developed from unfertilized eggs laid by the queen, and they do not appear till the summer is at its height. It is then, too, that young queens are born, on whom the continuation of the race depends. They pair with drones.

Worker humble-bees, like worker hive-bees, have a very short life —only about a month; and this becomes more marked as the summer goes on. No fresh broods are produced, and the numbers in the community steadily decrease. The old queen becomes bald and tired to death; the drones are driven off and perish; the workers become few. If there are any grubs left in the cells when supplies begin to fall short, they are devoured by the adults, including the young queens. But only the last are able to survive the winter, and so we come back to where we began.

It may be noted that the male or drone of the humble-bee genus (there are many different kinds) is much less helpless than the hive-bee drone and is able to forage for himself among the flowers. The humble-bee queen has, like the workers, an arrangement of pollen-collecting hairs and a curved, almost unbarbed sting which does not remain in the wound. The hive-bee queen has no pollen-basket and her sting is unbarbed, whereas the worker has a pollen-basket and a barbed sting which cannot usually be withdrawn from a wound. In other words, the differentiation between the functional females or queens and the sterile females or workers has gone much further in the hive-bees than among humble-bees. As a sting is a transformed egg-laying organ or ovipositor, we cannot expect one in drones.

A YEAR WITH A HIVE-BEE.—It is always interesting to follow an

animal through the year, though there is often more than one generation in that short span. There are annual animals, like most of the shrews, which do not live for more than a year; in the case of greenflies, on the other hand, the individual life is often over in a few weeks, and there are many generations in the course of the summer. What a long range from this to the centenarian tortoise, where one year must be very like another! Even there, however, we discern minor ripples on a very uniform curve of life, for the markings on the scales show for many years an alternation of a growing period in summer and a resting period through the winter. As an illustration of an animal's year let us take the hive-bee—very familiar, but not always thought of as a dramatic unity.

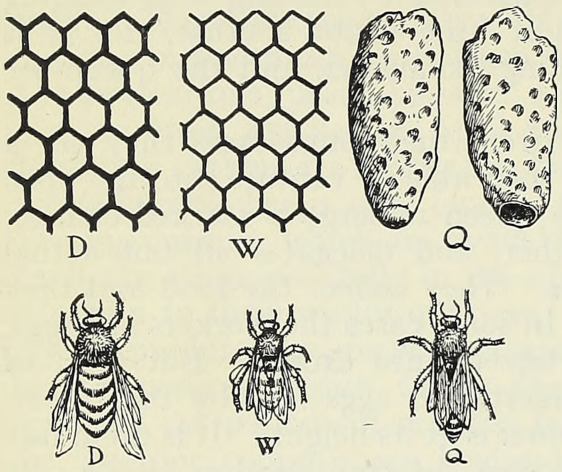


FIG. 108. HIVE-BEES AND THE CELLS IN WHICH THEY DEVELOP

Top row: D, drone-cells; W, worker-cells; Q, queen-cell, closed and open. *Lower row:* D, drone; W, worker; Q, queen.

When cold weather sets in the honey-bees snuggle together in the hive and pool their warmth. The head of one seems often to be under the tail of the next, like slates on a house; and those that get chilled on the outside of the cluster are replaced by others that have been warmed. They keep up tremulous movements, the muscles producing heat; and the fanning of their wings makes a humming which can be heard outside the hive. The temperature may rise to 90° F. inside the hive, while snow lies on the ground outside.

To continue producing heat the bees must have food, and the more work they have to do in producing heat, the more food they will require. It is, therefore, important to lessen the need for much feeding by having the hive well protected from the cold. It must be kept in mind that in the case of wasps and humble-bees only the young queens survive the winter, and that in a dormant state. The hive-bee's storing instinct has made it possible for the community to survive.

In spite of every care, there is often much mortality during the winter, especially if the spring is long in coming; so there must be a vigorous spring-cleaning before the business of the year begins. After this is over, the workers become busy bringing in supplies of nectar and pollen from the April flowers. They repair old honeycomb and

make new cells. The queen begins to be maternal, and, as she can lay three thousand eggs in a day, the population of the hive increases rapidly and the workers have nursing as well as foraging duties. A bee's egg develops into a grub in about three days, and a worker-bee is fully formed on the twenty-first day after the egg is laid. In an ordinary hive at the height of summer two or three thousand workers emerge every day.

The queen needs to have strong legs, for she is always walking about on the comb, and it is interesting to see the workers making way for her and attending to her whenever she appears. This is one of the 'traditions' of the hive. Some of the eggs are laid in the drone-cells, which are practically the same as the cells made for the storage of honey. These eggs are not fertilized, so the drones have a mother, but no father. The drones often put in an appearance in May, and spend their time in flying about outside the hive. They are anything but lazy, though it is true they do no actual work.

Early in the season, when the population is increasing by leaps and bounds, the workers make large queen-cells with thick walls. Each is something like a pea-nut, about an inch deep and a third of an inch across, always opening downwards. A queen-cell is considerably larger than an ordinary worker-cell.

When the queen, in laying an egg, fertilizes it from the store of sperms which she received from a drone during her nuptial flight in the previous season, such a fertilized egg will develop into a worker or into a queen. The decision is apparently in the hands of the workers, for the young grubs which get a very liberal supply of a certain thin, white food develop into queens, while those reared less generously develop into workers, who do not usually lay eggs. Workers have been seen shifting eggs from worker-cells to queen-cells, or enlarging a worker-cell so that it may be a cradle for a young queen. Queens, however, cannot be produced from grubs that are more than three days old. Something irrevocable happens on the fourth day, but naturalists have not yet been able to solve the mystery.

When the population of the hive is large and vigorous it is time to start a new community. In the case of many social insects a new colony is founded by the queen alone, but when a queen honey-bee flits she is accompanied by a retinue of workers. Preparations are made beforehand. The hive is always well provisioned; there is an abundant brood of worker-grubs; queen-cells are started and equipped so that there will be a choice of new queens to replace the old one, which, as a general rule, accompanies the first **swarm.**

It seems that before swarming there is also much activity on the part of scout-bees, which explore the vicinity in search of a new home, such as a hollow tree. When the excited crowd pours out of the

hive, and forms a dense cluster on a bush, it is the duty of the scouts to lead them to a new home.

A young queen left behind in the hive from which a swarm has migrated, or a young queen leading a second swarm, is not of much use unless she is mated to a drone. Without this she cannot be a mother of workers or of other queens. Thus, once in her life, she has her hour of freedom. On a sunny day she flies forth, and in the open air she is mated by a single drone. He pays with his life for his success. The queen returns to the hive and on the second day begins her maternal labours, which may continue for two or three years. At the end of the honey-harvest, if not before it, the drones are driven out to die of cold and starvation. If they are recalcitrant they are bitten and stung; and the drone-grubs are also killed in their cradles. A period of retrenchment sets in; the older workers die—' old ' usually means for a summer bee about six or seven weeks, though a longevity of three months is on record. The worker-brood is also sacrificed. The younger workers, always provided there is a fertile queen with them, cluster together for the winter; and such is the hive-bee's year.

DRONE-BEES.—It is difficult to get rid of old-standing errors, especially when they contain more than a grain of truth. Drones are not very idle; they fly about with praiseworthy persistence, always on the (usually disappointed) outlook for a queen-bee to fertilize. They have smaller brains than the workers and the queens; they are unpractised in ' homing ' and are apt to lose their way. Thus they may join hives to which they do not rightly belong. In days of plenty they are hospitably treated, and even in strange hives the workers will feed them as if they were brothers. But, when scarcity begins and the flight of the young queens is over, the workers are no longer tolerant. They hustle the drones, bite at their feelers and legs, and turn them out of doors. Here they soon die, for drones cannot find food for themselves and the evenings are becoming cold. When the drones try to sneak back into the hive, they may receive their *coup de grâce* from a worker's sting. But the account given by a careful investigator like Professor K. von Frisch is very different from the common one which depicts a sudden massacre, like a St. Bartholomew's night. There is a gradually growing antipathy on the part of the workers against their fatherless brothers; it increases in volume and intensity week after week until there are no drones left. This is the rule, a sudden massacre is the exception.

THE APPRENTICESHIP OF THE WORKER-BEE.—Natural History becomes more and more precise; and as observation deepens, so does the wonder. Thus by marking worker-bees in an observation hive Rösch has been able to follow their apprenticeship and their gradual promotion, so to speak, from one kind of duty to another in the

course of their short summer life of a month or six weeks. The young workers, that have just emerged from the pupa state, are turned to the task of preparing and cleaning wax cells in which the queen will lay eggs. After a few days they pass, or are promoted, to the status of nurses, watching over the young bees in their cells. At first they tend only the older larvae, supplying them with pollen and honey, but later they are trusted with the ' babies ' of the hive, which require a nutritious fluid secreted by the worker-bee from glands which begin to function at this time, about the tenth day of adult life. When the worker is a fortnight old, more or less, she leaves the nursery to spend a week in the general service of the hive, cleaning away refuse, distributing and storing food, and so on. Trial flights in the open may also be made, but on these first attempts there is no collection of pollen or of nectar. Finally, at the age of about three weeks, each worker is assigned the last of her indoor tasks, that of acting as guardian at the gate, preventing the entry of strange bees or other intruders. When this task is done, the worker-bee devotes all her remaining life and strength to the arduous work of collecting nectar and pollen from the flowers. Here, too, there is much division of labour, for the bee does not flit heedlessly from flower to flower, but, once given over to tapping one profitable and abundant species of flower, may keep to this for the whole of her outdoor life without ever entering another kind of blossom. But what is new in Rösch's study is the definite proof of a regular succession of tasks in the worker-bee's indoor life. The science of animal behaviour is growing apace.

THE BEE 'LANGUAGE.'—A careful investigation by Professor K. von Frisch throws a fresh light on an old problem—how hive-bees tell one another of their discoveries of nectar. The old theory was that the discoverer flies back to the hive with her spoil, and on coming out again guides her comrades to the feast. But this is not what happens. Frisch found that when a bee, carefully marked, of course, returns full of nectar to the hive, she executes a peculiar ' round dance ' on the comb. This excites the bystanders, and is the bee's way of telling of treasure-trove. If there has been no discovery, there is no dance. This explains how the number of new bees going to a discovered flower-patch automatically wanes when the supplies begin to be exhausted. There is less dancing.

But how do the new bees find their way without a guide? They do not wait for the discoverer, but issue forth to search for themselves. They are not without a clue, however, for they have sampled the floral fragrance lingering on the discoverer's body, and they search for flowers with that scent. The bee's world is very largely a smell-world.

But what if the nectariferous flower had no scent? What can the

clue be then? Professor Frisch's answer is very interesting. Bees have on their posterior body a protrusible glandular pocket which secretes a scent, recognizable even by man. When a discoverer finds a rich feast she excitedly protrudes the little scent-organ, and the blossoms are thus, as it were, sprayed with her scent. The searching bees utilize this clue. When the bees are collecting pollen its specific fragrance helps in the search, but there is again a dance that tells the tale. It is quite different, however, from the nectar dance.

It will be understood that this interesting method of conveying information is not in the ordinary sense a 'language,' for it is not vocal, and it does not express any judgment. Many animals have *words*, but so far as we know, man has the prerogative of making a sentence or of really saying something.

THE HOMING OF BEES.—Thirty years ago Bethe boldly suggested that the hive emitted some kind of radiation by which the bees were guided, much as ships and aeroplanes are guided to-day by 'directional' wireless signals. This theory not unnaturally provoked a vigorous controversy and further research; and the general result was the conclusion that hive-bees find their way home by utilizing landmarks. But the whole aspect of the question has been again changed by the recent work of Wolf. In his first paper he described a series of experiments in which the central idea was that of changing the position or appearance of the hive; and these experiments showed that the bees are guided partly by visible landmarks and partly by the odour of the hive. There was also evidence of a certain **sense of direction** located in the antennae; for it was found that if bees were carried away from the hive in closed boxes they became somewhat confused if the boxes were turned round frequently—just as a blindfold man is confused when spun round several times. But, if the antennae are first removed, the bees are no longer bewildered by this turning, though they do not make for home as certainly as before. Later experiments have confirmed the view that the bee has in its antennae organs which record movements, until they begin to 'lose count'—organs analogous to the semicircular canals of the human ear.

But the most striking of the experiments described in Wolf's second paper point in another direction. A hive was set up in a piece of waste ground almost devoid of visible landmarks, and it was observed that the bees spent an unusually long time in preliminary surveys. Then the bees were taught to come for sugar to a definite place—let us say 150 yards due north of the hive. A number were caught in boxes at the feeding-place, and some were presently released; they flew back to the hive, southwards. Others were carried in the boxes to a point 150 yards due east of the hive and there released; and these also flew southwards as before, though this course was now

taking them away from the hive. When they had travelled 150 yards in this direction, however (and they accurately 'estimated' the distance to ten yards!), they hesitated; and, apparently realizing that they were wrong, they proceeded to circle around until they found the hive by sight and scent. Apparently, then, the bees 'knew' in what direction they had come from the hive, and about what distance; and their first impulse was simply to retrace their flight without regard to such landmarks as there were. A further insight into this sense of direction was gained in experiments in which the captured bees were kept in their boxes for an hour before being released, either at the 'right' or 'wrong' places; as before, the bees immediately flew off, right or wrong; but they did not now fly due south, but at a definite angle to the west of this—and this angle was the angle through which the sun had travelled while the bees were in captivity. The bees were steering by the sun, as ants have also been said to do!

When Wolf repeated some of these experiments with a hive in a garden well supplied with landmarks, he found that the bees, after a few deceptions, learnt to disregard the sun and their sense of distance, and steered, so to speak, 'by the map'—that is, by the visible landmarks. They returned directly to the hive from whatever point they were released. It is one of the most interesting features of Wolf's work that his bees soon learned to disregard guides and indications which had proved, owing to the experimenter's interference, to be untrustworthy.

THE SEAMY SIDE OF THE BEE-HIVE.—It is interesting to watch a queen-bee moving restlessly over the comb—she is a great walker—and to notice how courteously the workers give way before her, backing off with their face to royalty. It is plain that she means much to them; they are assiduous in their attentions, bringing her food and dressing her hair. The beekeeper tells us of the disorganization that sometimes sets in, it may be within a few minutes, when he quietly removes the queen. In a short time, perhaps by some olfactory 'wireless,' the bad news spreads through the hive, and the heart is taken out of the workers. They are greatly agitated; they cease to work; they rush about seeking anxiously for the lost queen; they may extend their search outside the hive. 'If they cannot find her,' we read in Dadant's edition of Langstroth's *Honey-Bee*, 'they return to their desolate home, and by their sorrowful tones reveal their deep sense of so deplorable a calamity. Their note at such times, more especially when they first realize their loss, is of a peculiarly mournful character; it sounds somewhat like a succession of wailings in a minor key, and can no more be mistaken by an experienced beekeeper for their ordinary happy hum, than the piteous moanings of a sick child could be confounded by the anxious mother

with its joyous crowings when overflowing with health and happiness.' This is the rather soppy way people have of writing about bees! But the puzzling fact remains: the rapid disorganization which follows the removal of the queen-mother, and the rapid reorganization which follows her restoration. She is normally the keystone of the arch.

The experiment has been made of shifting a populous stock to a new place and putting an empty hive on the vacant site, this being done in the early forenoon when thousands of workers were ranging the fields. When these foragers returned and found an empty hive they were greatly put about. Of course, ' it was truly affecting to witness their grief and despair.' But when a little piece of brood-comb was given to them, containing eggs and grubs, their restlessness ceased. We are told that they recognized in this remnant something that saved the situation for them. But how are we to think of it scientifically? On the one hand, it will not do to say that they discerned the possibility of a future for their house! On the other hand, it seems equally extreme to be content with saying that the sight and smell of these full cradles sufficed to keep ageing the instinctive industry and integration of the workers. But the fact seems to be that in a very short time ' their restless motions and mournful voices ceased, and a cheerful hum proclaimed their delight. If someone should enter a building filled with thousands of persons tearing their hair, beating their breasts, and by piteous cries, as well as frantic gestures, giving vent to their despair, and could by a single word cause all these demonstrations of agony to give place to smiles and congratulations, the change would not be more instantaneous than that produced when the bees received their brood-comb! '

Here again there is too much ' sob-stuff,' but the objective facts are very remarkable, and they may serve to illustrate the outstanding quality which has won for honey-bees the admiration of an uncritical world. That quality, which finds many detailed expressions, is, we think, fundamentally a community-obsession, a socialistic instinct verging on the pathological. ' Nature,' Goethe said, ' is always taking advantage of her children's capacity for self-forgetfulness.' If we may continue the anthropomorphism, we might say that in the case of ants, bees, and wasps, Nature has taken a rather mean advantage.

Social bees and ants have a strong kin-sympathy. They like their kinsfolk, they stand by them, they feed them if they need sustenance. This is the root of a social urge that may be stronger than individual hunger, stronger than self-preservation. They do not *think* about the community, indeed, any more than they think about themselves; but there has come about an extraordinary suppression of individuality on the part of the great majority, namely, the workers. They find satisfaction in working themselves to death for ends which are

communal, not individual—for ends of which they are at most instinctively, certainly not intelligently, aware. The suppression of individuality, which has come about constitutionally, not ethically, has led to a pathetically **servile state,** all the more regrettable because the individualities are very fine even when repressed. The dexterity of ants and bees is as admirable as their industry; their pertinacity is as remarkable as their mutual aid. What we are trying to say is that while the individual skill and the co-operative team-work of bees may be called unsurpassed, their self-forgetfulness has been carried too far. This has come about, *not deliberately*, but as the outcome of a self-subordinating constitution which has been of great survival-value for the community, though it has jettisoned individuality. An evolutionary process sometimes acquires a momentum that carries it beyond bounds—sometimes leading, as in the case of the giant reptiles, to extinction, sometimes leading, as in the hive-bees, to hyper-socialism.

Let us take a glimpse of the seamy side. (1) The biggest blot is that the whole economy of the hive depends on the existence of an enormous body of labourers, which are *arrested females*. They have better brains than the queen-mothers, if that is any consolation, but they are normally non-reproductive. Their sex, we venture to think, has been transformed along social lines. Though unmated and childless, they are unsurpassed in mothering. (2) As we were saying, we watched the queen-bee, and we saw her lay twelve eggs in ten minutes. We were rather proud to see this—twelve eggs in ten minutes—but when we got home and turned up Langstroth, we found that a good queen could lay 3,500 in a day, for several weeks in succession! Now this is prodigious, but it is plainly a good example of Nature's way of carrying things too far. It is making an egg-laying machine of a masterpiece. Little wonder that the queen rarely survives her third year; and she is usually tired long before that. What a life—never allowed out of doors, only once in her life in the open air, nothing but tramping round the comb laying eggs, and dozing when the warm weather is over! Of course she is not allowed to nurse her children.

(3) Then there is the much belauded industry of the workers, which 'improve the shining hour'! It is almost maniacal. They do not rest even at night in the hive, but do indoor work to pass the time. No doubt they have considerable variety of work, but they soon grow old. Their brain-cells go gradually out of gear beyond all possibility of recuperation, and, naturally, most of them die somewhat suddenly. That is just as well, for if they become unable to work, their more vigorous sisters drag them out to die. There are no old-age pensions in the bee-hive. Some of those workers that are born in late summer

are able to survive the winter, but the average length of life of a summer bee is only a little over a month. (4) Far from attractive, from our point of view, is the method pursued by some hive-bees of rearing a good few queens, and then killing all but one while they are still within the cradle. There would be more to be said biologically for letting the young queens fight it out among themselves, but we believe that the usual method is that the first-hatched young queen kills her immature sisters. (5) To mention only one other blot, there is the wastage among the handsome and energetic males, now libelled by the word ' drones,' for only one of them mates with a queen and he dies instantaneously upon the very heights of love. As we have noted, any drones that survive till the end of the season are driven forth to perish of cold and hunger. No, we do not admire the root ideas of the bee-hive!

White Ants

WHITE ANTS.—These extraordinary insects are not related to ants, and they are often far from white. It is better to call them termites, a name to be pronounced in two syllables. They are ancient insects, distantly related to cockroaches, but very much by themselves. A few of the thousand species have been introduced into the south of Europe, but the vast majority are at home in tropical and sub-tropical countries, more familiar in their nests than in themselves, for they have made a fine art of self-effacement. Almost all of them like darkness, moisture, and stuffiness, so they hide themselves in tunnels and galleries, or in complicated nests or **termitaries** which are sometimes on the ground and sometimes on trees.

All termites are social, but the families or colonies differ greatly in their size and in their division of labour. Some consist of several dozen individuals or fewer; others have a population of half a million or of several millions. Most colonies show kings and queens, workers and soldiers, but some have at least a dozen different castes and sub-castes. There is a remarkable parallelism between white ants and true ants, but the former are more primitive, of more remote origin, and much less aggressive. The true ants, which belong to the wasp and bee order, *Hymenoptera*, have in most cases a poisonous sting, but white ants, which are placed in a special order, *Isoptera*, have no weapons except in the soldier caste. Among true ants there is complete metamorphosis—grub, pupa, adult; but there is little or none among the white ants. The workers among true ants are arrested females; the workers (and soldiers) among white ants are arrested individuals of both sexes. At the same time, the resem-

blances between ants and termites in their social organization and in many of their ways are very remarkable.

A common length for a male and female termite when they pair is about half an inch, and many of the full-grown workers are of similar dimensions. Among the structural features may be mentioned the strong masticating jaws of the workers, the thin cuticle, the long abdomen, the simple feelers, the frequent absence of eyes, the relatively

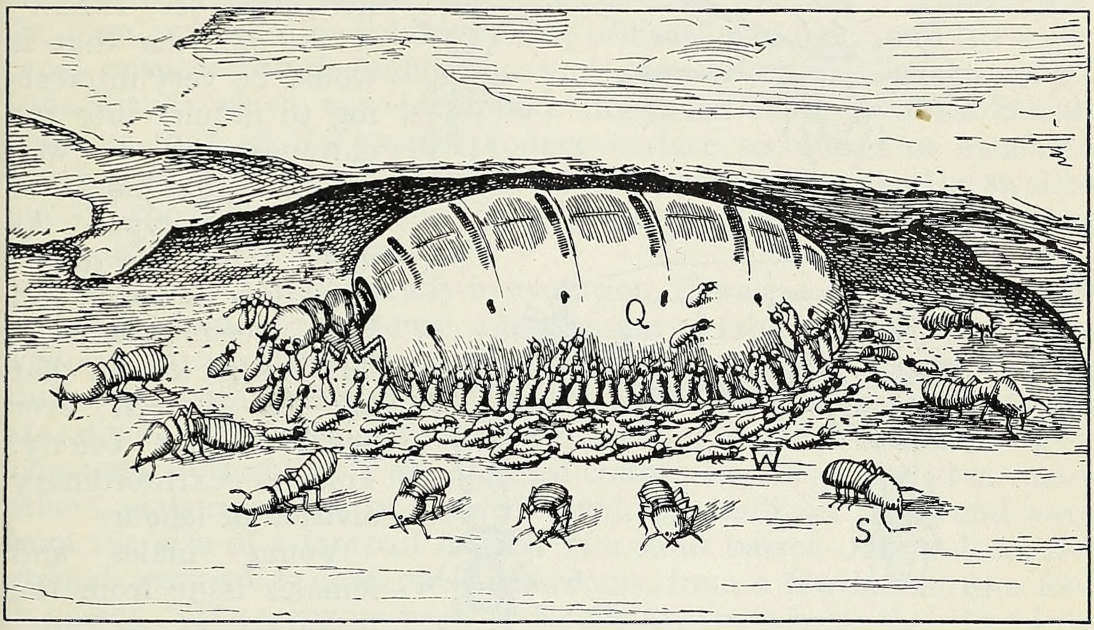


FIG. 109. A TERMITARY (COLONY OF WHITE ANTS OR TERMITES)
Q, queen; S, soldier; W, worker.

small brain. The fertile forms have two pairs of long, delicate wings, with few veins, and with a basal suture across which a breakage readily occurs; the workers and soldiers are wingless. Most termites are able to make sounds by working one part of the body against another; and in this way they seem to communicate socially. But these points require further investigation, and so does the nature of a very corrosive fluid which most termites secrete.

A typical colony includes: (1) the **completely developed male and female, or king and queen**; (2) **complemental males and females** which do not fully develop; (3) still more **arrested,** so-called ' **ergatoid** ' fertile forms; (4) the normally **sterile workers,** often of two sizes; and (5) the normally **sterile soldiers,** defensive individuals unable to feed themselves, often occurring in three different forms. The differences between these castes seem to be determined in the egg, and this at least is certain, that there are differences between the newly hatched fertile forms and the newly hatched sterile forms, before any differences in diet have set in. As we have said, workers and soldiers are

occasionally reproductive, giving rise to individuals like themselves, whereas the ergatoids can reproduce ergatoids, besides workers and soldiers, and the complementals can reproduce complementals, besides ergatoids, workers, and soldiers. As the kings and queens can produce any of the many forms, it looks as if there were, through the different castes, a successive diminution in the power of giving rise to other castes. In the section dealing with heredity (see INDEX) it will be seen that it would be very interesting to inquire into the chromosomes as well as the physiology of the different types. As many as sixteen different kinds of individual have been described; but it is not known that all the sixteen ever occur in one colony. This is extraordinary **division of labour.**

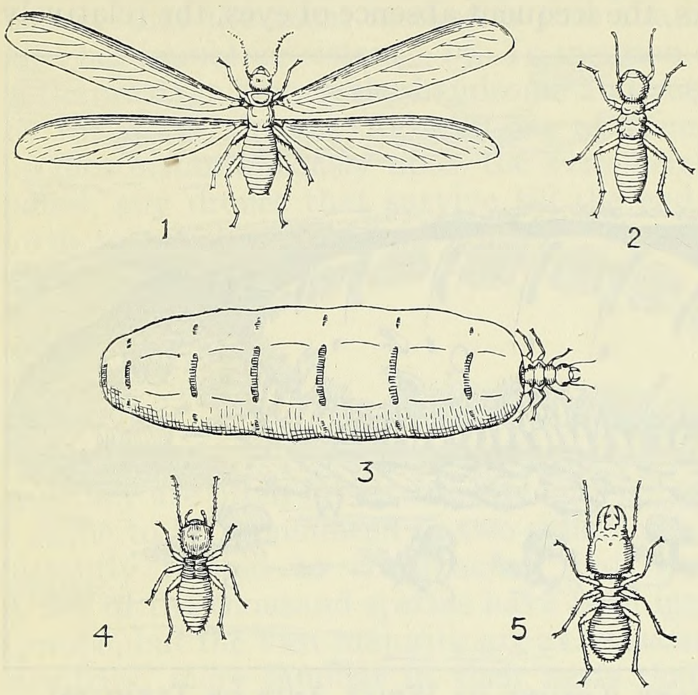


FIG. 110. SOME FORMS OF THE TERMITE
1, completely developed male or female; 2, complemental male; 3, fertile female, enormously distended; 4, worker; 5, soldier (note powerful jaws).

Young males and females issue from the termitary in an antenuptial flight, that is an excursion before they pair, but this does not last long. They soon come to earth, associate in couples, discard their wings, and begin to construct a nest. After they have made some progress they pair, and the queen settles down to the most extraordinary maternity in the world. After she has worker-daughters to help her and feed her, she often swells up to a length of three or four inches, her abdomen becoming grossly distended with food and ova. In some cases she eventually produces an egg every few seconds for hours on end, perhaps thirty thousand in a day. Ten million may be laid in a year, and this may continue for ten years. The complementals and ergatoids seem to be kept in reserve to replace the royal pair if these should die. The workers do the foraging, feeding, nursing, building, and repairing. The soldiers wield their large jaws with effect; and there is a strange type with vestigial jaws which are able to squirt a sticky fluid in the face of their assailants. It is altogether a grim business.

Termites feed mainly on woody materials and on decaying vegetation. In all the wood-eaters that have been studied there are numerous **partner-Infusorians** (see SYMBIOSIS) in the food-canal, and these make the dry-as-dust material available for the termites. By raising the temperature it is possible to kill the partner-Infusorians without hurting the termites, and in this way it has been proved that the termites cannot thrive without their symbionts. Workers feed one another with salivary juice and surplus food; they have also to feed the royal pair and the soldiers. The utilization of food from the food-canal ensures the dissemination and persistence of the alimentary Infusorians, which are not found anywhere else. Another quaint detail is that all the castes produce surface secretions or **exudates**, which the others lick off. This exudate is most copious on the swollen queen, who is therefore much licked; and there is often evidence that she is licked none too gently.

Termites make a fine study in evolution, there are so many grades of structure, domestic economy, and division of labour or **polymorphism.** The same is true of their housing activities, for some species content themselves with tunnels in wood and in earth, while others make elaborate edifices twenty feet high and strong enough to bear a man's weight. These stately termitaria are built, of course, on the ground; but many others, elaborated out of chewed wood, are built on trees, and vary from the size of a football to that of a flour barrel. Some beautiful ground nests are shaped like mushrooms, from a few inches to a foot in height. The compass nests of North Australia have their two long faces facing east and west, while their narrow gable-ends face north and south, thus reducing the exposure to the heat of the sun. What instinct! Many of the common South African termitaries are like washing-boilers turned upside down; they may be thick as molehills on a badly infested meadow; and they are strong enough to let a man stand on the top, as we have often proved. Most striking in a way are the dark-coloured nests that hang from the branches of trees in African and Indian forests, like great brown stalactites. The tree nests are all built of chewed wood; the ground nests are made of salivated earth, usually eked out in places with chewed wood. There are two noteworthy common features in termite nests—first, the presence of a central chamber where the queen lies and lays; and secondly, the absence of doors. For the light-avoiding or **lucifugous** worker-termites come and go to their feeding grounds along covered arcades of chewed earth and wood, or along tunnels in the earth continued by earthen arcades up the trees. We understand termites better when we keep in mind their general aversion to light, to dryness, and to draughts. Many of them are quite blind or nearly blind, but that does not seem to interfere with their being architects.

LINKAGES OF WHITE ANTS.—Termites are devoured by many insectivorous mammals, birds, and reptiles; and true ants are their inveterate enemies. So they are always passing into a new avatar. Their largest enemy is the Cape ant-eater or aard-vark, which burgles the termitaries by night and whips in thousands of workers on his long, worm-like, sticky tongue. On the other hand the termitary may afford more or less casual shelter to scorpions, snakes, lizards, and even birds, but the details of the interrelations are unknown. One would expect in most cases a speedy change of lodging, for the termites' jaws are irresistible, and there is also an irritant and corrosive secretion.

If we could imaginatively insert one leg of a giant pair of compasses in a termitary and describe a circle on a big scale with the other, what a variety of other life-circles should we intersect: trees and shrubs, fungi and Infusorians, ants and ant-eaters, beetles and birds, and so on and on. The circle of human life is, of course, intersected at many points. The termites devour floors, rafters, and furniture, boxes, books, and papers. It is futile to erect wooden telegraph posts, and there are places where it is dangerous for a man with a wooden leg to rest too long. The Australian bushmen make temporary ovens of the termite mounds and may even eat some of the salivated clay. The hillmen of India eat the termites themselves, and the queen with her four-inch-long abdomen, swollen with eggs and food, is said to be delicious. The earth of the termitary is often pulverized and used as a basis for tennis-courts and the like. Darwin would have enjoyed the modern disclosure of the intricate interrelations between termites and other living creatures, for it is but an extension of one of his central ideas—the interlinking of lives in a web of life.

THE PETS OF THE WHITE ANT, AND THEIR 'MORAL' FOR MAN.—When the naturalist turns from the animal life of Wild Nature to civilized human society, he cannot but be staggered by the contrasts. In civilized society disease is common; in Wild Nature it is extremely rare. In civilized society depressed vitality or sub-health is seen at every turn; in Wild Nature exuberant health is the rule. In civilized society ageing too often becomes a bad breaking-down; in Wild Nature (which does not, of course, include domesticated animals) we never see more than a gentle waning of powers. In civilized society sex often goes wrong and leads to disasters of body and mind; in Wild Nature it is exceptional to find anything morbid in the sex-life, though it must be admitted that ugly features occasionally occur. On the whole, there is no doubt that the naturalist turns from human to animal life with a sigh of relief.

When we ask why Wild Nature should be so far ahead of civilized society as regards health, we find part of the answer in the fact that animal life has been evolving for several hundred million years, whereas

men in the widest sense did not emerge till between one million and two million years ago. Thus the discordant and harmful has been more thoroughly sifted out of the animal.

It must also be remembered that every society acts as a shield over its members, and may allow of the survival of defective types that would be speedily eliminated if they stood on their own legs. Even among social animals we find illustrations of this; thus there are slave-keeping ant communities where the members of the ruling species require to be spoon-fed by their slaves. It is obvious that they would not survive for a week if there were no society; and so it is among men.

Another reason for human backwardness in achieving better health is to be found in the cleverness with which we can be medically cobbled, so that we are able to evade the salutary and deterrent penalties of bad habits. Moreover, modern life is interpenetrated by artificiality, and we allow our ambitions and love of pleasure to ride roughshod over considerations of health. Finally, in some cases, the glaring imperfections of our social arrangements make the securing of a healthy life a very difficult problem.

Disease means a breaking-up and disturbance of the normally harmonious routine of the body. (1) It may be constitutional or inborn; (2) it may be modificational, that is to say, induced by unwholesome surroundings, habits, and food; or (3) it may be brought about by parasites and microbes. Now, apart from man's interference, **microbic disease** is extremely rare in Wild Nature, and although parasites are common they are not usually very detrimental, for a live-and-let-live compromise is in most cases arrived at between parasite and host.

It must be admitted, however, that there is an *occasional* occurrence of a diseased condition in wild animals, and we wish to call attention to a remarkable case which seems like a ghastly parable. Let us return to the termites. In the huge societies of some of them there are insect guests or pets which are not merely tolerated, but fed and tended, the *quid pro quo* being in most cases a palatable or fragrant exudation—a luxury to the hosts. The guests or pets are usually small beetles, but sometimes flies, and they have acquiesced in a strange mode of life in the recesses of the dark ant-hill or termitary —a life of entire dependence on their owners, like that of a petted poodle on its mistress. Many of them suffer from **physogastry,** an ugly word for an ugly thing—the diseased condition that sets in as the penalty of being petted. In some cases the guest undergoes a sorry change. The posterior body or abdomen becomes bloated in an ugly way and may be protruded upwards and forwards over the front part of the body, whose size is often reduced. The food-canal lengthens and there is a large accumulation of fatty tissue. The

wings fall off. The animals become more or less blind. In short, the animal becomes degenerate and deformed. There is also a frequent exaggeration of the protrusions on which exudes the luxury which the pets supply.

According to Professor W. M. Wheeler, who has made a careful study of the physogastric condition, the peculiarities are the direct result of the unusual conditions in which the guests live, and here the parable becomes plain. The guests are living in darkness, which is prejudicial to good eyesight. They spend their life in the narrow passages of the termitary, which is mostly built of salivated earth, sometimes with the addition of chewed wood-pulp. But a cribbed, cabined, and confined habitat is apt to imply very little exercise, and lack of exercise tends to fat. This is part of the reason of the accumulation of fat, and another reason is to be found in the abundance of carbohydrate food which the termites give to their guests. Furthermore, there is a scarcity of oxygen inside the termitary; the air is slightly humid and distinctly stuffy. There is an anticipation of slum conditions, and the degenerate beetles are a warning to mankind!

But cases like these physogastric guests are very rare among animals except when we take account of thoroughgoing parasites, and there we have to do with degeneracy rather than with disease. There is practically no occupational or environmental disease in Wild Nature. And if an inborn or constitutional disease arises, as a variation in the wrong direction, it is usually nipped in the bud. A few extinct animals, known in a fossilized state, show some traces of bone-disease and the like, but this is very uncommon. Nature is all for health, not for mere absence of disease, but for positive health — full of vigour, initiative, and joy in life. This is one of Nature's biggest lessons for man: with all our getting, let us get better health; and if it is too late to be completely healthy, let us be as healthy as we can.

Useful Insects

One thinks at once of honey from the bee and silk from the silkworm, but perhaps it is more important to place in the foreground the part that insects have played and continue to play in pollinating many of the flowering plants. That is to say, many insects, such as bees and butterflies, that visit blossoms for the sake of nectar or pollen or both, carry the golden dust unconsciously from one blossom to another of the same kind, and thus secure **cross-pollination**, which may, of course, be also effected by the wind. The pollen grains dusted on to the moist tip of the pistil begin to grow, sending out long tubes which probe their way down the pistil to the *possible seeds* or ovules. A male nucleus from the pollen-tube fertilizes the nucleus of the

egg-cell in the *embryo-sac* of the ovule, and this is **fertilization.** Unless this happens there can be no beginning of another generation; no formation of an embryo. The more dusting with pollen, the more ovules become seeds; and it has been shown in some cases that the young plants in the seeds are more vigorous when there has been **cross-fertilization,** i.e. when a blossom is fertilized by pollen carried from another blossom of the same kind. For it must be noticed that in some cases the pollen from the stamens of a flower gets on to the pistil of the same flower, so that **self-pollination** is effected. This is habitual in peas, for instance.

It is difficult to be sure *how* the linkage between flowers and their insect visitors has been gradually perfected, but there is no doubt as to the fact that the beneficial visitors are well suited to reach the nectar and to dust another blossom with the pollen, and that the blossoms are well suited both to give and to receive. Flowering plants and their appropriate visitors have evolved together and are often adapted like glove and hand, though in a less one-sided way.

No illustration is better than the one Darwin gave in his famous book, *The Origin of Species* (1859). It should never become trite to us, especially as there are still things to be discovered in regard to it. Darwin found that if a hundred heads of the red clover (*Trifolium pratense*) were surrounded by muslin bags, so that insects could not reach them, not a single seed was produced, whereas another hundred heads left accessible to insects produced 2,700 seeds. It was not difficult to discover that the usual visitor was the humble-bee, for the hive-bees have not a tongue long enough to reach the nectar. 'The number of humble-bees in any district depends in great measure on the number of field-mice, which destroy their combs and nests; and Col. Newman, who has long attended to the habits of humble-bees, believes that "more than two-thirds of them are thus destroyed all over England." Now the number of mice is largely dependent, as every one knows, on the number of cats; and Col. Newman says: "Near villages and small towns I have found the nests of humble-bees more numerous than elsewhere, which I attribute to the number of cats that destroy the mice."' We have quoted part of Darwin's account of this linkage, which is typical of many. What he called field-mice are now called field-voles (*Microtus agrestis*), but this makes no change in the general argument: The more cats the fewer field-voles; the fewer field-voles the more humble-bees; the more humble-bees the more clover-seeds—a good instance of the interrelations in the **web of life.** But our general point at present is simply that the most useful insects are those, such as bees and butterflies, which secure the cross-pollination of many kinds of flowers.

In another part of this book, that dealing with man's practical

relations with animals, something will be said of silk and of honey, of lac and of lake, so we shall not do more here than mention a few of the most useful insects.

Many insects, such as ants and termites, do useful service in devouring dead animals and dead plants. Did not Linnaeus say that three flies would destroy a dead ox more quickly than a lion could? The disappearance of the dead bodies of small birds and mammals is largely due to burying beetles, and a common sight in Egypt is the industry of the scarabees in rolling home their little balls of cow-dung. There is no doubt that insects should be ranked high among the **cleansers of the earth.**

A number of insects are actually used as food, such as some large caterpillars and grubs. Grasshoppers and locusts are sometimes eaten, and the list includes Mexican water-boatmen (*Coriza*), Australian bugong-moths, the pupae of the salt-fly (*Ephydra hians*), washed up in millions on the shores of the Great Salt Lake of Utah. Even black ants (*Camponotus*) are relished by some who like strong flavours, and ' would resent being called savages.'

There are all sorts of out-of-the-way uses: thus blisters are made from various beetles, such as the oil-beetles and the ' Spanish fly '; ornaments are made of beetles' wing-covers and the wings of butterflies; pearl-like coccids (*Margarodes formicarium*) found on the roots of some plants in the West Indies are used to make necklaces; fire-flies and katydids become playthings.

Injurious Insects

Dr. L. O. Howard, chief of the Bureau of Entomology in the United States Department of Agriculture, refers very forcibly to the menace of insects. ' It has become perfectly plain that if human beings are to maintain their hold on this globe, if they are to continue to exist, they must learn to control insects. So the entomologist has risen in our esteem. In him and the results of his work lie our hopes for the future comfort, happiness, and prosperity, and even the very existence, of mankind.' In Great Britain the attacks of insects are marked by moderation as compared with what occurs in warmer countries, yet we suffer considerably from aphides, bean-weevils, crane-flies, diamond-back moths, elaters, flea-beetles, gout-fly, *Hypodermas*, and so on for the other letters of the alphabet. Insects destroy what is growing and devour what is stored; they attack domestic animals and man himself; they are vehicles of disease; their injuriousness is as incalculable as their usefulness. But when we pass from a small, highly controlled, and often cold country like Great Britain to an immense and often warm country like the United States, almost defiant in its

vastness, the importance of insects increases cumulatively. When enormous areas are under cultivation for some particular crop, such as cotton, there are terrifying possibilities of overwhelming multiplication. This is particularly true when an insect pest is introduced or introduces itself from elsewhere and runs riot in temporary freedom from its natural enemies and in the enjoyment of a new abundance of food. Thus the cotton-boll weevil passed from Mexico to the southern United States, and has done appalling damage in the cotton belt. Similarly with the gypsy-moth, which was introduced into America from Europe about 1868, and has been terribly destructive to trees, from which the caterpillars sometimes eat off almost every leaf. So with the codling-moth, the corn-borer, the Japanese beetle, the Mexican bean-beetle; and there are many other instances of the disasters that follow the discovery of a new abundance and a partial escape from the severity of the struggle for existence. We begin to understand why the entomologist is the hope of the future. Dr. Howard goes on to tell us that the annual loss by fire in the United States is 143,600,000 dollars, but the annual loss due to insects is 800,000,000 dollars. Insects destroy 10 per cent of the animal products, 20 per cent of the fruits, and 22 per cent of the wheat. 'It has been estimated that the money loss from the work of insects in the United States exceeds two billions of dollars yearly. To put it in other words, insects in the States nullify the expended labour of a million men.' So there should be a living wage for the economic entomologist!

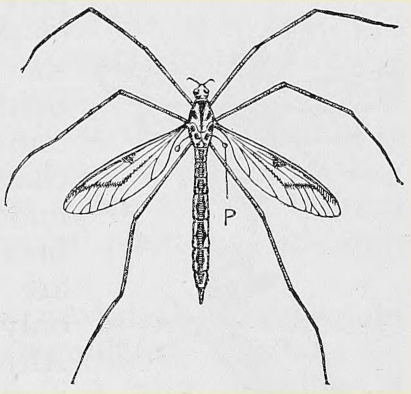


FIG. 111. CRANE-FLY
P, posterior 'balancers' or halteres.

LEAF-MINERS.—At the height of summer the leaf-miner is having the time of its life. The leaves are at their best, and the leaf-mining larvae are eating out characteristic tunnels, which are, so to speak, their signatures, for the expert entomologist can often name the insect from the shape of the tunnel. Some are curiously like little snakes and were long ago interpreted as devil's marks. But others are like stars, which might have been interpreted more optimistically. Others are like the tracks of slugs, and others are spirals like the shells of snails. The Natural History interest is their **specificity**; that is to say, each kind of miner has its own; they are like signatures. Just as a particular kind of gall-insect usually induces in a particular plant a particular kind of gall, so each leaf-miner has its specific way of tunnel-making. In the majority of cases the boring larva keeps to the middle tissue (*mesophyll*) of the leaf, sometimes in the upper half (*palisade parenchyma*), some-

times in the lower half (*spongy parenchyma*); but one occasionally comes across a neat worker that hollows out all the green tissue along a particular line, leaving only the transparent epidermis above and below. In a few minutes in the garden one can gather half a dozen different kinds of mines, made by different insects.

Mines are made by the larvae only, and most of them belong to the orders *Lepidoptera* and *Diptera*. In other words, most of the mines are the work of minute caterpillars or minute maggots. A comparatively small number are made by the larvae of saw-flies in the order *Hymenoptera*, and by the grubs of small beetles. Those that have been longest adapted to this mode of larval life remain in their mines till they are about to change into winged insects, and some actually undergo the metamorphosis within their tunnel, breaking out at the critical moment. But there are others of later evolution that are miners only during the first part of their larval life. After having gained strength at the leaf's expense, they take their departure, and adopt some other habit and habitat. In a monograph like that recently published by Professor Martin Hering, of Berlin, one gets information as to the ways in which the different kinds of miners can be distinguished by their style of tunnel-making. Thus if the skin of the leaf is puckered or folded, or if there is a minute circular opening on the under-side, one may be sure that the miner was a *caterpillar*. But if there is any 'herring-bone' pattern, one may be sure that the miner was a *maggot*. This would not be more, however, than the beginning of identification.

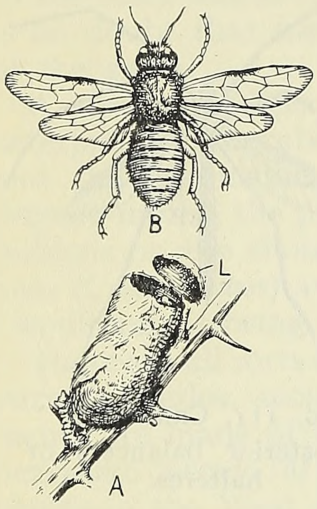


FIG. 112. SAW-FLY
A, pupa-case with lid (L); B, adult.

If the mother of the miner is a *saw-fly*, which is not very often, she inserts the egg in the tissue of the leaf, for she has an egg-laying boring instrument. In the other orders, the egg is simply attached to the surface of the leaf, sometimes above, and sometimes below, and the newly hatched larva bores its way in. There are cases where the larva begins to eat into the leaf before it has got more than its head out of its egg-shell, which thus remains to close the door when complete entrance has been effected.

Mining larvae are generally limbless, but many have minute projections that give them leverage in their tunnel-making; the head tends to be flattened; the mandibles or jaws are suited for sharp cutting; in short, the miners are in many ways adapted to their peculiar mode of life. In the mining caterpillars it is interesting to notice that the silk glands, which open on the lower lip of ordinary caterpillars, are in most

cases practically suppressed, unless it be for a short time immediately before the great change or metamorphosis. This is one of the many instances of the *economizing tendency* that is so often illustrated in organic nature. If an organ is not needed it tends to disappear.

A mine forms a habitat safe from most enemies except leaf-eaters, but it is also an indication of a specialized taste. In the great majority of cases a particular kind of leaf-miner is found on one kind of leaf, sometimes on one species only, sometimes on several related species. In the minority the miner is less selective. The specialism is connected, no doubt, with the kind of food that suits the larva best, but one must not forget that the mother-insect also reacts to the stimulus of the suitable plant when she deposits the eggs on the appropriate kind of leaf. In connection with the miner's food, it is interesting to notice that it consists in most cases of the **leaf-proteins** only; and they are more specific than the sugars or starches which are not utilized as food. It is probable that every species of plant has its own particular protein.

Most caterpillars, as every one knows, eat a great deal, as one would expect from their rapid growth and their accumulation of stores for the future ascetic aërial life. They get rid of a large quantity of undigested or indigestible food, which goes by the name of 'frass.' Now the question arises: How do the mining caterpillars deal with their waste? Only a few feed on sap; most chew the solid cells of the leaf. How do they get rid of the undigested cellulose? It is very unusual to find any elimination of the waste on the outside of the leaf. The two main adaptations that have been observed are interesting. The 'frass' examined microscopically is found to be very fine in the grain, so that it dries up quickly. In other cases it is deposited at one particular place in the mine, and this tidiness probably makes for health.

We have spoken of the mines as shelters for the miners, but whenever an animal finds a particularly safe retreat some other creature sooner or later makes the same discovery. Thus there are quite a number of small *Hymenoptera* and *Diptera* that lay eggs, through the skin of the leaf, in the soft-bodied tunnel-makers. What exquisiteness of sense to insert an egg in a body that is neither seen nor felt! Some empty leaf-mines have been obviously torn open, and this seems to be the work of the beautiful **golden-eye flies**, which bite in and suck the miner out. There are some birds that have learned to slit open large mines, while others, like tits and goldcrests, are said to swallow small leaves for the sake of the miners within. One cannot help thinking, however, that big-brained creatures like birds might have found something more profitable. It is possible that the miners do not mean more than appetizers to the birds.

Leaf-miners are very common on some garden plants, like chrysanthemums, on shrubs like azaleas and syringas, on fruit trees like apples, and on conifers like larches; and yet they are not among the worst enemies of plants. For one reason, they do not spread from leaf to leaf; for another reason, they have a predilection for the weaker leaves and the weaker plants. They may thus tend to eliminate the less fit, which is always to the good. Obviously, however, they do harm on the whole, and it is wise to pull off mined leaves and burn them. It is interesting that the leaves themselves react against the destructiveness of the miners. Thus when a stretch of leaf has been more or less isolated by a twisting tunnel, the leaf sometimes forms a water-conducting bridge which may save the part whose veins have been cut. The bridge is made of what are called **callus-cells**, which do not normally occur in the leaf. Life is very resourceful!

THE COTTON WEEVIL.—The Mexican cotton-boll weevil (*Anthonomus grandis*) is never more than a sixth of an inch in length, but it has shaken several continents since it crossed the border of the United States in 1892. It has overrun nearly the whole of the cotton belt in the course of some thirty-five years. The female beetle bites small holes in the buds or the flower of the cotton plant, and lays her eggs there. The eggs hatch out into hungry grubs which feed inside the blossom or the capsule ('boll'). They sink into the pupal phase, whence beetles emerge which recommence the destructive work, continuing to eat for weeks or months. In the northern parts of the invaded cotton belt only about 2 per cent of the beetles survive the winter, and yet the annual loss due to their ravages in the States has been estimated at £50,000,000. Professor Carpenter quotes from the President of the New Orleans Cotton Exchange, who declared that 'national prosperity is threatened by the ravages of this insect.' Arsenical sprays are used on a vast scale and the price of arsenic increases threefold; disused tin-mines in Cornwall are reopened for the sake of the arsenical by-products; aeroplanes are needed to spray the infested cotton, and the factories are busier; but we must not pursue the *plus* and *minus* ripples further. The big fact is a huge and disastrous loss and the shaking of an immense industry, and this is but a conspicuous instance of the intersection of human life by insects.

A QUEER CREATURE.—Every now and then one is pulled up by the queerness of some living creature. It may be a queerness in bodily architecture: take a bat, for instance. It may be a queerness in life-history: take a liver-fluke, for instance. Or it may be a queerness of behaviour: and a good example will be found in the habits of an American grub, the young of the green June beetle or fig-eater (*Cotinis nitida*), studied by Miss Anna Laura Hintze. The grub is of considerable agricultural importance, for it is fond of potatoes,

turnips, carrots, and the like. It makes burrows in the ground, but it wanders about on the surface at night. Its constitution seems to be wound up to alternate between burrowing and reappearance on the surface, for experiment proved that its coming up did not depend primarily on such conditions as dampness, darkness, temperature, or food-supply. But the peculiar feature is that it moves about on its back, both when it is on the surface and when it is underground. By waves of contraction passing along its back it wriggles along on the ground with its legs waving uselessly in the air! If it is turned on to what one might call its natural position, it brings its two ends together, falls over on its side, and then gets on to its back again. This is a strange habit and yet it seems to work well. On the surface a rate of about two feet per minute was observed, and the average was rather over a foot and a half. In shallow soil the maximum was about an inch and a half in a minute, but the locomotion was not quite continuous.

How can one explain the habit of wriggling along on the back instead of using the three pairs of legs? Perhaps the answer is to be found in the fact that the legs are used to assist the jaws in digging. They grip into the soil and throw it along the upturned ventral surface. The numerous ventral bristles push upon the upper wall of the burrow when the dorsal muscles jerk the body along. It may be, then, that the legs are not used for locomotion because they are of more use in burrowing. When all is said, however, it remains a queer thing that a grub should move along upside down. We do not know of any other grub with this peculiarity.

CURLY-LEAF IN BEETS. — A minute bug or leaf-hopper called *Eutettix* is responsible for spreading the disease in American sugar-beets known as 'curly-leaf.' The little beet leaf-hoppers occur in huge numbers, there may be a million to an acre; and they are, of course, very destructive in sucking the sap of plants. But they do a worse injury in spreading a plant disease. It seems that when one of these leaf-hoppers bites an *infected* beet-plant, it sucks up with the sap an ultra-microscopic organism. After thirty-six to forty-eight hours it is able to infect a fresh beet-plant, and the disease shows itself in about two weeks. Just as a mosquito carries the ultra-microscopic organism that causes yellow fever, so this *Eutettix* bug carries the germ of 'curly-leaf.' It is suspected that other insects are vehicles of similar plant diseases, as in the case of one of the potato's maladies. In the milky juice of some spurges or *Euphorbias* there lives a kind of trypanosome allied to the microscopic animal organisms that cause sleeping sickness; and one of the bugs, *Stenocephalus* by name, is said to be responsible for spreading the infection from one spurge to another. Let us gather the threads together again.

Diseases in plants or animals that are produced by microscopic living creatures are called microbic, and three different kinds of **microbes** have to be distinguished: (1) minute single-celled animals, e.g. the malaria organism (*Plasmodium*) and the sleeping sickness organism (*Trypanosoma*); (2) minute single-celled plants, e.g. *Bacteria*; and (3) ultra-microscopic micro-organisms, which pass through good filters, the filterable viruses, such as that of curly-leaf. Quite apart from the causes are the **carriers**, such as mosquitoes, tsetse flies, and the leaf-hopper *Eutettix*.

DEATH-WATCHES.—'Not only in the grandioes roof of Westminster Hall, but at Hampton Court, Gray's Inn, Bath Abbey, St. Paul's, and elsewhere, generations of the mischievous death-watch have been devouring the roof-trees of ancient structures, reproducing the species in lofty and inaccessible timbers which alike provide food and homestead, cradle and grave.' The death-watch (*Xestobium tessellatum*) is a small beetle whose larvae devour old wood, which they honeycomb with their tunnels. Their presence is betrayed by the numerous holes, about the thickness of knitting-needles, and by the falling out of characteristic oval buff-coloured pellets which represent the undigested remains of the wood that has passed through the food-canal of the larvae. If we may judge from what is true of a near relative, *Anobium*, it is probable that the young death-watch is assisted by partner yeast-plants to make the most of its dry-as-dust food. The full-grown beetles emerge from the timber or from oak trees in May or June, and the male signals to his desired mate by tapping with his head on the wood. The female lays as many as eighty eggs, in most cases in crevices, and the hatched grubs follow cracks into the interior. For the first summer and for two more they tunnel in the wood and feed on the sawdust. In the third summer they come near the surface and turn into chrysalids. The beetle that is formed as the outcome of the metamorphosis is ready in the autumn, but it does not usually emerge and fly away till the following spring. Great damage is done by the burrowing grubs, but Professor Lefroy points out that the ravages can be balked. 'The basis of a treatment is the application, by means of a spraying-machine, of a liquid that thoroughly wets the timbers, penetrates any decayed parts, enters any beetle holes, gives off a vapour that destroys the grubs inside and leaves behind an invisible, unalterable film of poison which kills emerging beetles or the grubs seeking to enter.' The expense is largely that involved in making a scaffolding to reach the timbers, but a church roof can be treated in a day and the total cost may not exceed fifty pounds. Various kinds of poisonous spray are obtainable from reputable firms.

HOUSEHOLD INSECTS.—Those who find pleasure in old furniture

must always be on the look out for the small **boring beetles**, which burrow in everything wooden. They are very destructive; thus the repair of the damage they did to the oak beams in the roof of Westminster Hall is said to have cost the National Exchequer about £100,000. There are two common kinds—the furniture-beetle and the larger death-watch to which reference has just been made. The **common furniture-beetle**, that makes furniture worm-eaten, lays its eggs in crevices in the wood, and these develop into little white grubs, less than a quarter of an inch long, that at once begin to tunnel. They thrive on the unpromising diet of dry wood particles, apparently aided, like the death-watch, by partner yeast-plants in their food-canal, and in a year or more they turn into beetles that can fly. In combating furniture-beetles and other pests, a great deal can be done by repeated use of turpentine, but a bad infection requires severer treatment.

Cockroaches are not very black and they are certainly not beetles, but why should we grudge our friends the delight of correcting us

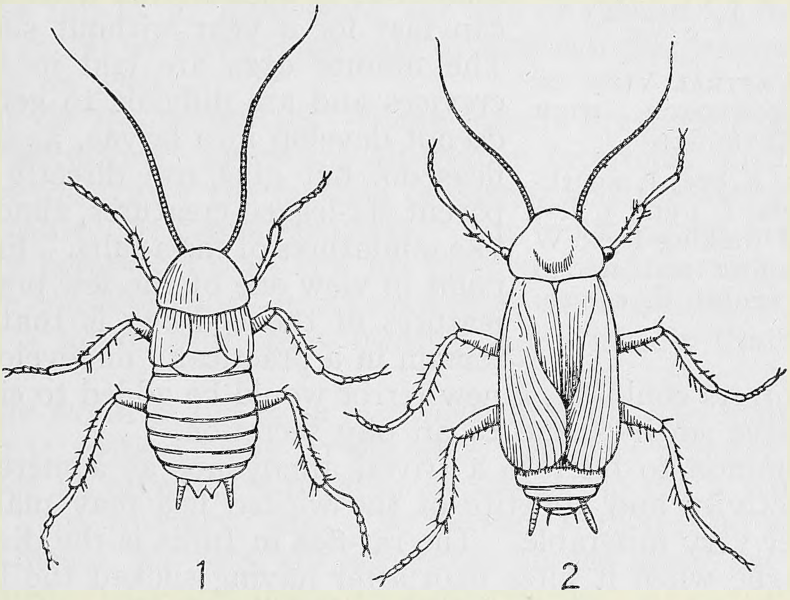


FIG. 113. THE COCKROACH
1, female; 2, male.

when we use the old-fashioned name 'blackbeetles'? It is certainly much better than the American name 'roach,' which is nonsense. Like our rats, our household cockroaches are aliens from warmer lands, and we cannot wonder that they enjoy the shelter and the crumbs which we too generously provide. Considered detachedly they are not unattractive insects, but they are pests in houses. They foul food; they have a repulsive smell; and they eat everything except

cement, which should therefore be used to fill up every chink and hole. Pyrethrum powder is very useful, and brushing corners with creosote is effective. Cockroaches always have **partner (symbiotic) yeasts** in their alimentary canal, and these ferment the multifarious food.

The great French novelist, Balzac, speaks feelingly of the heavy, depressing *odeur de pension*, which is still familiar. It is usually due to the presence of the **bed-bug** (*Cimex lectularius*), a flat rust-red insect that shelters in cracks and crevices, and emerges at night in search of a victim. It has a beak enclosing four needles, and the fore-part of the food-canal acts like a suction-pump. The probability is that these obnoxious insects were primarily suckers of vegetable juices, and have secondarily taken to a diet of blood. They are often numerous in uninhabited houses and they can fast for a year without succumbing. The minute eggs are laid in batches in crevices and are difficult to get at; they do not develop into larvae, as the eggs of fleas do, but give rise directly to transparent six-legged creatures, almost exactly like miniatures of the adults. From man's point of view one of the few praiseworthy features of the bed-bug is that its wings remain in a practically undeveloped state. If these horrors could fly, a new terror would be added to civilization. The repulsive smell is due to an oily secretion.

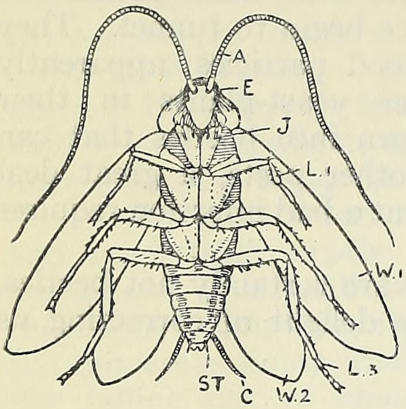


FIG. 114. VENTRAL VIEW OF MALE COCKROACH, WITH WINGS EXTENDED

A, antennae; E, eye; J, mouth-appendages; L 1 and 3, first and third walking legs; W 1 and 2, first and second pairs of wings; C, cercus; ST, style.

It is common to refer to a trivial annoyance as a mere flea-bite, but the activity and appetite of the wicked flea may make even a philosopher very miserable. The **rat-flea** in India is the disseminator of the plague when it bites man after having sucked the blood of a rat infected with the plague bacillus (*Bacillus pestis*). Of course it is not the case that fleas 'bite,' but what short word can we use for the vertical puncturing and the subsequent suction? Some houses are intolerable owing to **fleas**, which seem to lie in wait for their victims. The eggs are whitish sticky ovals, about a fortieth of an inch long, and they are laid in rugs and mats or in crevices of the floor where dust and débris accumulate. They develop into active larvae, like minute white threads with long hairs, and these feed on dry fragments of animal origin. After twelve days or so the larvae or maggots sink into quiescence and go through their metamorphosis in pupa-cases

of silk entangled with dust and tiny fibres of wool. In the summer the hungry flea emerges in about a fortnight, but in winter the quiescence may last for months. Fleabane (*Pulicaria*) burned will banish fleas, and so will various commercial preparations. But all will be in vain if the floors are not kept clean.

Even in Britain and the northern States a house may become almost uninhabitable because of small ants, but the invasion usually yields to spraying with formalin and fumigating with sulphur. Though they may be troublesome in their numbers, even on the dinner-table, they do no great harm except to the serenity of the lady of the house. It is very different with the termites (q.v.), badly called 'white ants,' that are so common in many warm countries; for they devour the wooden furnishings and everything related thereto, from the books in the library to the corks in the cellar. It is often necessary to place the feet of the table-legs in china cups which cannot be perforated. The termites dislike the light of day and may work stealthily out of sight till they reduce the table-leg, for instance, to a shell.

Of course this is far from being the end of the list of the enemies within the gates; we have given only diverse samples, enough perhaps to be going on with.

RAVAGES OF HOUSE-MOTHS.—Some insects are beneficial, such as bees and silkworms; some are altogether injurious, such as those mosquitoes that carry the malaria organism and the tsetse flies that carry the cause of sleeping sickness. But most insects are half and half, partly helpful to man and his interests, and partly prejudicial. Thus, if we consider wasps in a broad way, we must admit that while they spoil a lot of fruit, they destroy many insects that are pests of plants.

While the world of life is *on the whole* 'friendly' to man, we need not expect it to be always on our side. And as regards particular insects, such as earwigs, it is often impossible to get a true bill, for there is a 'con' to every 'pro.' So we turn with mental satisfaction to clothes-moths, for they are altogether on the black list except to the naturalists, who find them very interesting.

Like cockroaches, they have linked themselves to man, for unlike the casual biggish moths which come in at the open window of an evening and are fatally compelled to fly into the lamp, the true clothes-moths are always with us, and do not visit the outer world at all. They have doubtless evolved from near relatives that feed on lichens, bark, and so forth in the open country.

True clothes-moths are species of *Tinea*, in the group *Tineae*, among which are the smallest of all the small moths. There are over two dozen species of *Tinea* in Britain, but only three or four of these have become permanent foes in man's household. A very common

species, especially in summer, is *Tinea pellionella*, about half an inch across when its wings are fully spread. If we could forget the caterpillar's depredations, we should call the moth beautiful, for its fore-wings are shining greyish yellow with three vague brownish spots on each, and the hind-wings are whitish grey. It does not eat at all; that is the privilege of the tiny caterpillar, which has a dull whitish body and a reddish-brown head.

Peculiar and admirable is the tunic or case with which it protects itself as it roves about among our precious furs. The outside of the case is fashioned of fragments of hair or fabric; the inside is lined with soft silk which the caterpillar secretes from behind its mouth. The case is open at both ends and varies, of course, in colour and texture according to which of our garments the caterpillar has been corrupting. At one end we can see the head and the three pairs of locomotor limbs sticking out, while the posterior pro-legs serve to grip the inside of the case. When we shake the fur coat, the caterpillars retire completely within their cases. As long as they continue feeding and growing they have periodically to moult their outer husk or cuticle, and they have also to add to their case. This they do at both ends, for they are actually able to turn right round inside their tube.

When it is full grown, the caterpillar becomes a chrysalid inside the case, a little yellowish-brown oval, and before it passes into quiescence it fastens each end of the case by silk threads to the fabric or to the sides of some safe crevice near by. In about three weeks there emerges the moth, soon able, as we know, to fly and run quickly. Its hunger is over; its business is to get mated. In furs and feathers the mother lays the minute eggs, and out of these come the hungry caterpillars.

Another common clothes-moth, rather larger than the case-bearer, is *Tinea biselliella*. The fore-wings are shining yellow without spots; the hind-wings are paler; the head is reddish. Instead of making a portable coat, this caterpillar constructs a fixed tunnel in the fabric. Into this it retreats when disturbed, and within its shelter it becomes a brownish mummy-like pupa, wriggling uncannily when disturbed. The caterpillars are busy in the summer months, and will eat woollens, such as flannels, as well as furs.

Larger still, with a wing-span of about three-quarters of an inch, is the tapestry-moth (*Tinea tapetzella*). The fore-wings are black basally, then mottled creamy white; the hind-wings are shining brownish grey with long fringes. When the moth is resting, the hind-wings are quite hidden, and the insect appears as a long narrow object, black in front and white behind. The caterpillar devours coarse fabrics like carpets, and it makes no case or tunnel, simply lining its burrowed galleries with its own silk.

These are the three commonest clothes-moths, but there are relatives

to which the loose popular term is sometimes applied. Some of the larvae have discovered strange niches of opportunity: thus there is one species of *Tinea* that occasionally devours the sheaths of the horns of living antelopes. Most of the *Tineae* show this predilection for horn—a strange dietetic specialization. Hairs and feathers are, of course, made of horn or keratin, as are our finger-nails.

Very precious furs should be wrapped up in paper with no loose ends, for the moth cannot get through paper. We have known of the skins of small mammals being entirely protected, for over a score of years, inside wisps of thin paper. It is also useful to have balls of naphthalene or camphor or the like among the furs and clothes, for the moths are repelled by such odours. When the tiny caterpillars have got a footing, exposure to fresh air and sunshine often effects a speedy clearance.

BLOOD-SUCKING FLY LARVAE.—We usually, and rightly, think of the larvae of **Muscid-flies** as scavengers living on decomposing organic matter, such as carrion. The term 'Muscid' includes the flies related to the common house-fly (*Musca domestica*), such as blue-bottles or blow-flies, green-bottles, and even the famous or infamous tsetse fly of Africa. All of them have important 'fly-characters' in common, such as having only the first pair of wings well developed, the hind pair, which are fully formed in most insects, being represented by little quivering '**poisers.**' These Muscid-flies all agree in a little trivial feature, that a bristle borne by the feeler or antenna is feathered. A straw shows how the wind blows, and there is often some minute character, like this feathered bristle, that proves the blood-relationship of a hundred different kinds or species of animals. A shibboleth betrays them. A *touch* of common nature proves them all akin. This is one of the most familiar of Natural History experiences.

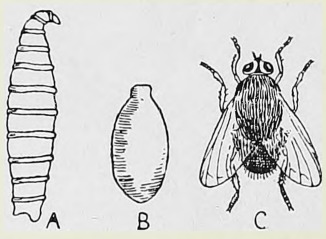


FIG. 115. STAGES IN LIFE-HISTORY OF BLUE-BOTTLE FLY (*Musca vomitoria*)

A, larva; B, pupa; C, adult.

In some flies the habits of the **maggots** are peculiar. There is a **green-bottle fly** that lays its eggs amongst the wool of sheep, and the maggots get into the skin and produce bad sores. Another member of the same genus (*Lucilia*) sometimes contrives to lay its eggs in the human nostril, whence the maggots may pass up to the frontal sinuses and cause great suffering. On the other side of the account there is an Algerian fly, like a house-fly, whose larvae devour the eggs of the dreaded locust.

Roubaud has shown that the larvae of several African blow-flies, which rest in the soil during the day, come up at night and suck the blood of sleeping mammals, such as aard-vark and wart-hog. They cannot complete their development without feeding on the blood of

some backboned animal. In some cases they attack man, coming up out of the earthen floor of the hut.

Long ago (1845) the French entomologist, Leon Dufour, discovered that the larvae of a green-bottle fly sometimes attack nestling swallows. He noticed that the larvae were ' gorged with blood,' and concluded that they were external blood-sucking parasites, not scavengers like most of their kind. Since Dufour's observations similar cases have come to light, and it is plain that we should keep an eye on the habits of Muscid larvae.

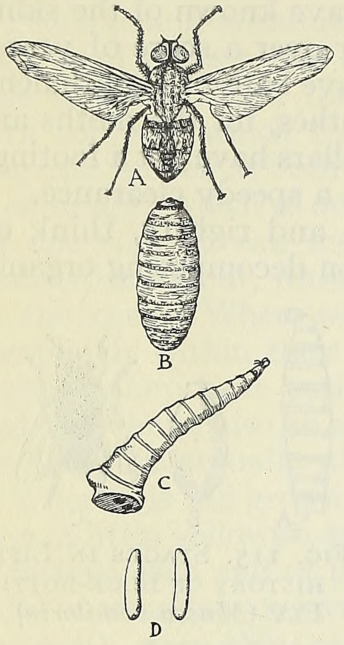


FIG. 116. STAGES IN LIFE-HISTORY OF BLOW-FLY (*Calliphora erythrocephala*) A, adult; B, pupa; C, larva or maggot; D, eggs.

One of the recent cases is reported from San Francisco by O. E. Plath, who found numerous larvae and pupae of a particular **blow-fly** in nests of goldfinches and Nuttall sparrows, and was able to demonstrate the **blood-sucking.** Experiments with tame canaries and three other kinds of birds showed that the larvae were not confined to goldfinches and Nuttall sparrows. The blood is stored by the larvae in a special crop, and a meal lasts for several days. The blood seems to be essential to the larvae, for the development is not completed if they do not get their draught. Out of sixty-three nests, representing six species of birds, thirty-nine were found infested by the blood-sucking larvae. About 5 to 10 per cent of the nestlings die from loss of blood, and others that become full-fledged are seriously weakened. It would be interesting to look into some British nests in this connection.

CABBAGE BUTTERFLIES AND ICHNEUMON-FLIES.—The caterpillars of the cabbage whites (see Fig. 107) are often disastrously abundant. Another year they may be present in small numbers. One reason for this is to be found in the varying success of the check imposed by those **ichneumon-flies** which lay their eggs in the caterpillars. When the ichneumon-grubs hatch out they devour the caterpillars from within. Dr. G. Jegen found that out of 1,360 pupae collected in winter, 1,216 were fatally **ichneumonized**, that is to say, about 90 per cent. Three kinds of ichneumon-flies emerged—*Pteromalus puparum*, *Microgaster glomeratus*, and *Pimpla instigator*. It is important not to collect or destroy the ichneumonized pupae of the cabbage whites, for that means killing the ichneumon-grubs and thus reducing the ranks of the useful ichneumon-flies. The ichneumonized dead pupae may be recognized by their immobility and darker colour. They are usually

found in places more exposed and more accessible than those in which the non-ichneumonized pupae occur. Dr. Jegen raises a curious point. He found that the males of the large white were 60 to 80 per cent commoner than the females; and he thinks this may be because the ichneumon-fly (*Pteromalus puparum*) prefers the caterpillars that are going to develop into female butterflies. But why should it? And, if it does, how does it discriminate?

FOR AND AGAINST WASPS.—Some years there are so many wasps that the fruit crop suffers badly and thin-skinned people are troubled. Another year they are conspicuous by their absence. But people who find in this a reason for unmixed congratulation are probably taking a short-sighted view, for wasp-grubs are fed for the most part on chewed insects, and some of the kinds that are devoured are certainly injurious. Moreover there are a few wasps that help in the pollination of the blossoms of fruit trees; and this must be set against the damage they afterwards do to the fruit.

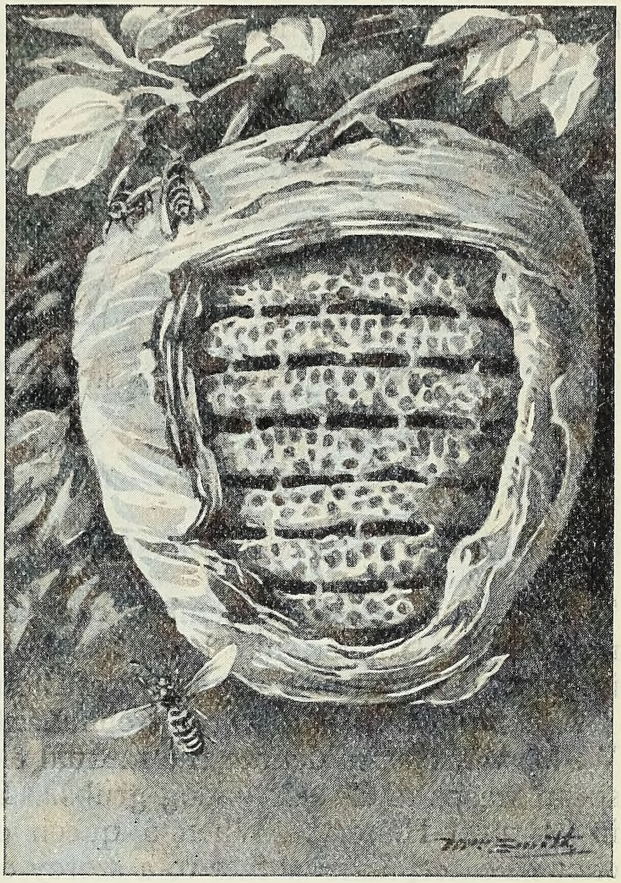


FIG. 117. WASPS' NEST

We have not facts enough as yet to come to a secure conclusion regarding the pros and cons of wasps from the view of man's interests. We have to balance one fact against another; and we cannot be fair to wasps until we know, for instance, the numerical proportion between the injurious and the beneficial insects which they devour, or how far their appetite for nectar counterbalances their appetite for the sweet juices of such fruits as plums and grapes, apples and pears.

According to the experts, the original wasps were predatory, feeding mainly on other insects, and had likewise the habit of laying their eggs in the living or paralysed bodies of other insects, just as the related **ichneumon-flies** (p. 296) do. Thus the wasp-grubs were wont to be reared on fresh meat, and that primary diet has still to be

supplied even when the young wasps develop in the cradles of the familiar papery nests.

If it be true, as seems highly probable, that bees evolved from wasps that abandoned the predatory tradition and took to specializing on nectar, the storing of which was facilitated by the secretion of wax, it is very interesting to find that some social wasps store honey in their nests and use it to eke out the animal food which the grubs normally require. There is also a small group of solitary wasps, known as the *Massarines*, which provision their cells with a paste of honey and pollen, as is the custom with solitary bees.



Fig. 118. Wasps' Nest on Laburnum

Just as in human sociology, where we see the differences between a wheat society, a rice society, a banana society, and so on, the ramifications of animal evolution have often had to do with changes of diet. As the distinguished French physiologist, Claude Bernard, said long ago: 'L'évolution, c'est l'ensemble constant de ces alternatives de la nutrition.' Hunger, like love, has been a fundamental evolutionary impulse, but we must also think of the rôle of preferences in both.

A conundrum of a word, **trophallaxis,** was invented by Professor W. M. Wheeler to denote the mutual exchange of food between adult social wasps and their young grubs. It is one of the strangest facts in Natural History. When a queen or a worker-wasp comes with chewed caterpillars or flies to a storey of cells filled with young brood, the hungry larvae protrude their heads and open their mouths. They are fed like young birds in the nest, but the feeding is not one-sided. From the salivary glands of the grub a fluid trickles out, and this is greedily licked up by the adult wasps. Thus there is an exchange of food, *trophallaxis* between adults and larvae. The vibrations of the nurse's wings incite the larvae to an *instinctive* protrusion of their heads, and then their mouths water by a *reflex* action.

In many cases the exchange is very unfair, for the worker knocks at the door of many grubs to which she has no food to offer. If the salivary elixir is not forthcoming, the worker may seize the grub's head in its jaws, and ram it back violently into the cell. This usually has the desired result. Many of the details are very eerie. Thus the very young newly emerged workers and the males or drones are very

keen to get the sweetish secretion, but they have nothing to give in exchange. Nevertheless they exploit the larvae; and we can understand that it is advantageous for the community of adult wasps if one crop of larvae after another is forthcoming throughout the summer months. Yet it works wonderfully well, for if the demands on the larvae are excessive, deficient nutrition will be the result and the arrested larvae will give rise to more workers who differ from queens in having poorly developed ovaries. These imperfect workers continue the nest-building and the foraging, and they distribute the food among their larval sisters. Little wonder that they have an appetite for drops of elixir!

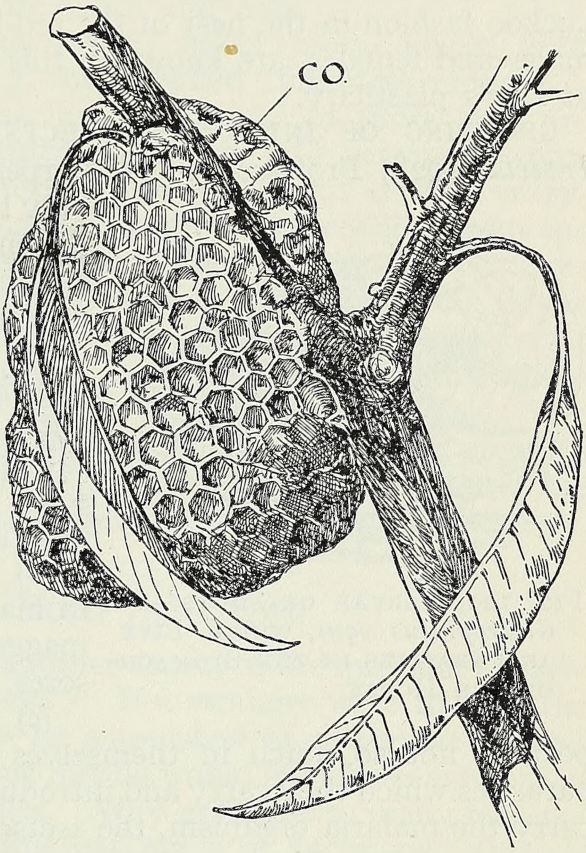


FIG. 119. WASPS' COMB (CO) ON A TWIG

As the number of workers increases, the burden on the individual is lighter, and some of the workers produce **parthenogenetic eggs** which develop into males or what we call drones. But with an increased number of foragers food becomes more abundant; the larvae are more generously fed; and they develop into fertile and fertilizable females — in other words, into the queens, which alone survive the winter. This is not the whole story, but we see again how important the food question is, and how it tends to regulate automatically the domestic economy of the wasps' nest.

BRITISH WASPS.—There are seven British species of the genus *Vespa*, and *all but one* have the same type of life-history, namely this: A single queen, fertilized (or, more accurately, inseminated) the previous autumn, starts a nest and begins to lay eggs in early summer, and gradually becomes the mother of a large family of several thousands of workers. Towards late summer or autumn, the males and the young queens are born.

A convenient account of the different British kinds, including the *hornet*, and of the various types of nest that they build, can be obtained from the Ministry of Agriculture and Fisheries, and it can be strongly

recommended to all who wish to do wasps justice and to know about them with pleasant precision.

The common wasp, the German wasp, and the red-legged wasp are usually underground builders; the tree wasp, the Norwegian wasp, and the hornet usually build in trees, bushes, and buildings.

We said *'all but one,'* and the exceptional species, to which we referred, is the somewhat rare wood wasp, which lays its eggs in cuckoo fashion in the nest of the red-legged wasp. No workers, only males and females, are known in this peculiar case—another instance of Life's plasticity.

GROUPING OF INJURIOUS INSECTS.—In his masterly *Biology of Insects* (1928) Professor G. H. Carpenter says that a swarm of flies may be a greater obstacle to man than a lion in his path. Can we arrange the injurious insects according to the nature of their injuriousness?

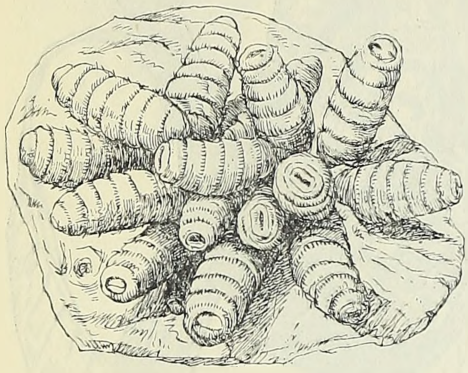


FIG. 120. LARVAE OR 'BOTS' OF *Gastrophilus equi*, WHICH LIVE AS PARASITES IN THE STOMACH OF THE HORSE

(*a*) There are man's direct enemies, like the stinging hornets and the army-ants. The floating hairs of procession caterpillars are very troublesome to some people when they get into the nostrils.

(*b*) There are insects parasitic on or in man, such as lice on the skin and maggots that may develop in open sores.

(*c*) There are insects that are important not so much in themselves as because of the microbes or parasites which they carry and introduce into man's body. Mosquitoes carry the malaria organism, the tsetse flies carry the sleeping sickness organism, house-flies spread the germs of enteric fever, lice carry the microbes of typhus fever. A small threadworm or *Filaria* is also introduced into man's blood by a mosquito's bite.

(*d*) Again, if we substitute for man the animals that are useful to him, we find that some insects are their direct enemies. Thus gad-flies provoke cattle.

(*e*) Similarly, the sheep-ked, a wingless Dipterous insect, *Melophagus ovinus*, bites the skin of the sheep; the maggots of the horse bot-fly (*Gastrophilus equi*) occur in the horse's stomach; the maggots of the ox warble-flies, e.g. *Hypoderma bovis*, are internal parasites of cattle.

(*f*) And there are insects that introduce into certain animals the germs of serious diseases, e.g. a kind of sleeping sickness in horses and cattle.

(*g*) A third set of three groups must be recognized for those insects

that do to useful plants what others do to man and to useful animals. Thus many caterpillars devour useful plants and green-flies suck their sap. The Colorado beetle destroys potato plants.

(*h*) The grubs and the adults of the cotton-boll weevil may be mentioned as terribly important parasites of the flowers and fruits of the cotton plant; and the same is true of the larvae of a small moth which destroys the cotton crop in Africa and Asia.

(*i*) It is believed that various insects infect useful plants with minute disease-causing germs, e.g. the so-called 'filterable viruses.'

(*j*) Another group of injurious insects consists of those that are destructive to man's stores, furniture, clothes, and permanent products. In warm countries the termites or white ants devour everything wooden and everything that approaches the wooden, from the books in the library to the corks in the cellar. Of great importance are the weevils and other beetles that devour stored corn, the larvae of the flour-moth that bore in biscuits, the death-watch beetles that make tunnels in furniture and rafters, and the tobacco-beetles whose grubs feed on leaf tobacco and cigars.

Hundreds of other examples of injurious insects might be given to illustrate these ten groups, but we have said enough to show the diversity of ways in which insects intersect the circle of human interests.

How Insects Hold their Own

Let us return for a moment to another aspect of the question already raised: *How do insects get on so well?* If a stranger were to visit the earth to-day he would certainly be astonished at the great success of Insects, just as in the Cretaceous Age he would have been astonished at the great success of big Reptiles. Why are there so many insects? Many naturalists estimate the different kinds of backboned animals at about twenty-five thousand; but of backboneless animals there are ten or even twenty times as many, and most of these are insects. But some authorities point out that about six thousand new insects are discovered every year, and that there must now be two millions. Certainly the number of insect species is six times that of all other animals put together.

One reason why there are so many insects is that insects have an extraordinarily successful make-up. When animals emerged from the water long ago, and colonized the dry land, one of their difficulties was that while there is much more oxygen in the air than in the water, it is not so readily available. It does not pass so readily through a hard skin as through the delicate skin or the gills of water animals. But insects and their relatives hit upon a new device—that of a system of **air-tubes** carrying fresh air to every hole and corner of the body.

The oxygen is necessary to keep the fire of life burning, and the abundant aëration of the insect's body is part of the secret of the insect's intense activity and success. The blood never becomes impure. Moreover, the beating of the wings helps to drive used air out, letting fresh air in, and flying helps the breathing.

The second reason for the success of insects is in their power of **flight,** for a flying creature can secure a measure of safety by rising into the air. It can quickly follow moving food; it can easily migrate from scarcity and drought to plenty and moisture; it can lay its eggs far away from the dangers of the ground.

The third reason for the success of insects is in their remarkable development of **instinct.** They have been able to acquire a good stock of ready-made tricks, a readiness to do effective things right away, without learning. It has its drawbacks, this instinctive capacity, but it makes for success as long as the unexpected does not happen.

The fourth reason for the surpassing success of insects is in their **variability** and their manifold associations with plants. While the fundamentals of an insect's body are always the same the details vary without end, and this has enabled insects to find innumerable niches of opportunity.

A Russian naturalist has of late directed attention to another reason for the success of insects. In backboned animals the skeleton —made of living gristle or bone—is *inside* the body; in insects the skeleton—made of non-living chitin—is *outside* the body. Now it is argued that this different kind of body-architecture made it possible for insects to become very small without ceasing to be very effective. They were in a position, by becoming so small, to win an entirely new place in the animal kingdom. So their apparent insignificance became their real power. Diminution of size is more practicable when the skeleton is an outside skeleton of light, durable, non-living chitin than when the skeleton is inside and made of heavy living bone. Most of the very large insects are extinct; the teeming insect world of to-day consists in the main of small creatures, filling the gaps, as it were, among the higher animals which have evolved on quite a different tack.

Yet another reason, behind them all, is that many insects are extraordinarily *prolific.* How often have naturalists repeated Huxley's calculation that if the descendants of a single mother green-fly or Aphis were to survive and multiply they would be represented at the end of the first summer by a horrible welter that would weigh down the population of China ! The common house-fly lays eggs in batches of 120–150 at a time, and may lay five or six of these batches during its short summer life of about three weeks in hot weather. At the end of summer, if all survived and multiplied, and if there had been

six generations, the progeny of a single pair, if pressed together into a solid mass, would occupy a space of something like a quarter of a million cubic feet, allowing 200,000 flies to a cubic foot.

As these things do not actually happen—though there are, of course, transient plagues—the question arises: *How are insects kept in check?*

HOW INSECTS ARE KEPT IN CHECK.—The possible over-multiplication of insects is a cloud in the world's sky. For if they did get the upper hand, it would be an end of everything. But this seems a highly improbable catastrophe since the *Balance of Nature* has been very firmly adjusted in the course of millions and millions of years. We are aware, indeed, of the frequent occurrence of a local and temporary menace, but it tends to disappear automatically. Thus when locusts eat up all the plants and turn a green and pleasant land into a disastrous desert, they have to shift their quarters or perish. Whether they do this on foot before they have developed their wings, or whether they fly away in numberless hosts, there is enormous mortality. Things right themselves in the course of time. What are the most important factors that keep insects in check?

(1) First of all, we should be grateful to the much grumbled-at weather, especially to the rain and the cold. Apart from hard-shelled types like beetles, most insects are delicately built creatures, and very susceptible to bad weather. Thus the human inhabitants of North Temperate regions have, apart from the northern midges and mosquitoes, very little idea of the multitudinousness of insect-life in genial countries.

(2) It is a fortunate thing for us that many insects are palatable, for they are kept within bounds by the appetite of their enemies. They are devoured by mammals, such as ant-eaters; by birds, such as swifts and swallows; by reptiles, such as chamaeleons; by amphibians, such as the common frog; by fishes, such as the trout that thin the crowds of larval may-flies; by spiders and scorpions; and not least by other insects. We must not forget the **insectivorous plants,** such as the sundew and butterwort on the moor, the Venus's fly-trap in the Carolina swamps, and the pitcher-plant in the tropical forest.

(3) Some insects fall victims to parasites which they harbour. Thus in the autumn we sometimes see a house-fly that looks far from happy. It may turn round and round very rapidly as if it were in pain, and on the surface of its body there is a white dust. The fly is being destroyed by a fungus, *Empusa muscae,* whose delicate threads riddle the body and form millions of white spores on the surface. If we kill the dying fly, we may see that its internal organs are partly destroyed. Here may be mentioned the quaint '**stick-caterpillars,**' which are victimized by another fungus (*Cordyceps*) and carry a remarkable fructification, sometimes six inches in length, on the front of

their head. The fungus penetrates through and through the body and kills the caterpillar.

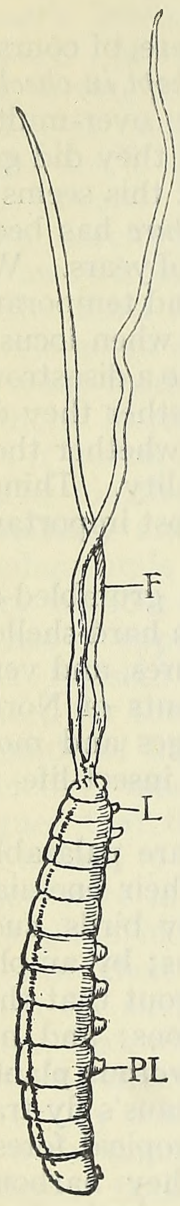


FIG. 121. STICK-CATERPILLAR, WITH FUNGUS

F, fungus; L, thoracic limbs; PL, pro-legs.

In another chapter we have mentioned the **horse-hair worms** (*Gordius*), which spend part of their life as parasites in insects. Thus the minute larva of *Gordius tolusanus* bores into a larval alder-fly (*Sialis lutaria*), or may-fly, and rests and feeds there for a winter. If the mature insect be eaten by a beetle, such as *Pterostichus*, the young horse-hair worm develops and kills its host by absorbing the tissues. When the worm is nearly mature—it may actually be five inches long—it bores out of the beetle into water or damp earth. There are other worms of somewhat similar, thread-like appearance called *Mermis* which live for a time in grasshoppers and beetles and some other insects; but they are not nearly related to the Gordian worms.

Some of the parasites that infest insects are very interesting because they occur also in very different hosts, to which the insect links them. Thus the biting-louse (*Trichodectes canis*) of the dog harbours a bladder-worm or larval tapeworm, which also occurs in the dog-flea (*Ctenocephalus serraticeps*). The dog, biting at its irritated skin, may swallow either of the insects just mentioned. If so, the bladderworm in the insect becomes a tapeworm (*Dipylidium caninum*) in the food-canal of the dog. The six-hooked microscopic larvae of the tapeworm are passed out from the dog and may be entangled on its coat, whence they may find entrance into the bodies of the lice or the fleas. Then the story begins again. In this case the insects are the '**carriers**' or vehicles of the parasite—a good instance of linkages or **interrelations** in the web of life.

In his valuable *Biology of Insects* (1928) Professor G. H. Carpenter shows how animals very far from one another may share a common parasite. Thus the tailed larva of a fluke, after developing inside a water-snail, may penetrate a water-beetle, which may be eaten by a frog—the host of the mature fluke. Another larval fluke gets into the aquatic larva of a may-fly or harlequin-fly, and the winged insect may be caught by a bat, in whose food-canal the larval fluke becomes an adult. These **parasitic chains** are of much interest.

Many of us must have noticed that the big black **dor-beetle** (*Geo-*

trupes) is often beset on its under-surface and legs with numerous yellowish mites (*Gamasus coleopterorum*) which suck the insect's juices. Similarly with water-beetles and other aquatic insects like water-boatmen; they are often attacked by young forms of **water-mites** (*Hydrachnids*) which feed as adults on the little crustaceans badly called water-fleas.

The serious disease of hive-bees, known as **Isle of Wight disease**, is associated with the presence of a minute mite (*Acarapis woodi*) which lives in some of the air-tubes or tracheae. In that strange shelter, the mites suck the juices of the body and often choke the air-tubes by multiplying. A common, but not invariable, symptom of the disease is 'crawling.' The bees are unable to fly, and creep about in an ineffective way which often ends in death. It is probable that the mites by blocking certain tracheae prevent the muscles from getting their due supply of oxygen. The minute parasite has not been found in any wild relative of the hive-bee, but another form has been reported in a grasshopper.

To sum up, then, *insects are kept in check by bad weather, by hungry enemies, and by various kinds of parasites.*

Some Interrelations of Insects

In addition to their rôle as parasites and as the hosts of parasites, insects enter into many interrelations or **linkages** with one another, with other animals, and with plants. This is the subject of the sub-science of **Ecology**, and we wish to select a few good examples.

GALLS.—Every one knows the **oak-apples**, like wooden marbles, on oak trees, and the '**brier sponges**,' like dense tufts of hair, that are common on wild rose bushes. There are scores of common galls, with this in common that they are the retorts that plants make to the intrusion of some other living creature. The intruder may be a bacterium, as in the **root-tubercles** of clover and other leguminous plants; or a fungus, as in the immense galls on the root of alders and the **witches' brooms** on various trees. It may be a Nematode worm, as in the **ear-cockles** of wheat; or it may be a minute mite. But most galls are connected with insects, especially with Hymenoptera; and the most finished galls, like oak-apples, are made by **gall-flies** in the family *Cynipidae*. In spite of their name these 'gall-flies' belong to the order Hymenoptera, and are not far from the 'saw-flies' and the 'Chalcid-flies,' which may also make galls. Our understanding on the subject has been recently deepened by some very interesting studies which Dr. Werner Magnus has made on gall-making Hymenoptera, and by some welcome experiments, such as injecting extract of gall-fly

eggs into suitable plants and observing the consequences of the provocation.

According to Magnus there are two chapters in gall-making, the general and the special. In the general chapter there is a response, such as increased growth, in the plant tissue surrounding the intrusion, but nothing new is formed. In the special chapter, however, there is a development of something specific and distinctly novel, which occasionally seems quite out of keeping with the character of the normal plant. Thus it is possible to find a velvety gall on an oak tree or a prickly gall on a smooth variety of rose.

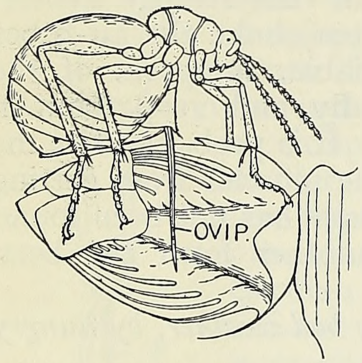


FIG. 122. GALL-INSECT, LAYING EGG IN BUD
OVIP, ovipositor.

In many a gall of the oak-apple type, the central cavity which contains the white grub is surrounded by plant tissue rich in protein reserves, and outside that there is another zone of tissue rich in carbohydrate reserves, while the outermost layer is hard or sometimes corky, so that the oak-apple with its prisoner may actually be still fresh when the leaves of the plant have withered away. It is a long-standing puzzle why the plant should be so generous, so to speak, to an enemy, but perhaps there may be some advantage in shutting the intruder in a well-stocked prison, for this keeps it from wandering about and doing more widespread damage. It is possible, however, that the plants cannot help themselves. They have to grow in a new way when the ordinary stimuli are disturbed, and the frequent perfection of their new growth may simply mean that the plants cannot react to the provocation except in an orderly way.

(1) In saw-fly galls the first chapter follows from the wound made by the mother insect in inserting an egg. There may be some fluid secretion accompanying the puncture, which provokes stronger development of the adjacent plant tissue; but the growth has been shown to be independent of the presence of the egg. The important factor is the *wound*.

(2) In Chalcid-fly galls the first chapter is induced either by the puncture on the mother's part, or by wounds made by the newly hatched grub. In exceptional cases it may be an exudation from the egg that induces a stronger growth of the simple tissue round about.

(3) In ordinary 'gall-flies' (*Cynipids*) there may be a mechanical wounding due to the mother insect or to the larva, but in the main the wounding is chemical. It is produced by a poison or toxin that exudes from the opened egg or from the newly hatched larva. This poison is not readily diffusible, but it brings about a solution of the

immediate adjacent tissue, and the larva sinks into a soft cradle. This is not surprising, for it is well known in other connections that the introduction of a strange protein may have a disintegrative or dissolving effect on the victim. This is familiar in the case of snake poison. So far we have been dealing with chapter one.

In all hymenopterous galls, the second chapter—the characteristic or specific growth of the gall—is due to the persistent influence of the living and developing larva. The gall is not the result of a poison or virus introduced once and for all into the plant; it is the outcome of a continued series of provocations emanating from the intruder, including the salivary juice, but more besides. Magnus compares the influence of the grub to the influence of the fertilized mammalian ovum when it effects fixation in the wall of the womb. It calls into activity a succession of growth-changes and tissue-changes that would not occur if it were not there. In all growing there is an interplay of stimulations and regulations, and we may think of the gall-larva just as if it were a peculiar part of the plant. It intrudes on the physiological stage and the normal routine of the play is altered.

A few galls may be reckoned as beneficial, if we include the root-tubercles caused by certain bacteria on leguminous plants, which make the use of atmospheric nitrogen possible. Some galls are positively injurious, like the 'ear-cockles' of wheat and the **ergot** of rye. Most galls are indifferent, and their structure, often finely finished, is, we think, to be interpreted simply as an orderly answer-back to a quite unusual set of provocations due to an intruder. In more learned words, an unusual stimulus evokes a well-regulated response. May we suggest the collection of half a dozen different kinds of galls, so that, *with the real things before us*, we may ponder over a problem that goes very deep into the mystery of life?

LEAF-CUTTING ANTS.—There is much that is dramatic in the activities of the leaf-cutting ants (*Atta*) of Guiana. It has long been known that they cut neat segments of leaves from the trees, and transport these to their great underground nest, holding them up like green parasols. On digging into the underground metropolis, a business which required caution because of the bites of the soldiers, Mr. Beebe had the good fortune to see groups of worker-ants chewing and chewing for all they were worth. They were making a sort of spongy paste or pabulum on which a certain fungus is grown. This fungus has never been found outside the leaf-cutters' nests, and it affords the entire food-supply indoors. The workers weed off other fungi and they also keep their own particular variety from fructifying, for what they delight in is a liquid that occurs in drops at the ends of the fungoid threads, and these cease to be formed if the fungus ceases to be vegetative.

But the keen-sighted explorer discovered something even more striking. When a winged queen leaves the ant city on a **nuptial flight**, she takes with her a little pill of the precious fungus, holding it beneath her mouth. When she descends from mid-air, having been fertilized in her flight, she burrows into the ground and begins egg-laying. But she does not lose her pill of fungus; it is carefully treasured for days to come. The queen lays many eggs, and has to eat some of them in order to sustain her energies. Soon, however, some of the eggs hatch out into workers. These eat more surplus eggs, but they are soon able to issue forth and bring in leaves. Then is the time for planting out the fungus so carefully preserved all the while. Besides the ordinary workers there are **soldiers** with scythe-like jaws, and peculiar dwarfs or '**minims**' which accompany the workers on their expeditions, though unable to cut off leaves. They seem to get woefully tired on the home journey, and three or four may be seen jumping on to a worker-ant, and holding firmly to the green parasol. There is a tiny blind cockroach that lives in the nest and gets its food by licking the leaf-sap from the big ants. Mr. Beebe tells us that when the queen sails off on her honeymoon, one of the massaging cockroaches sometimes goes with her, all unbeknownst. This is not all, for— but, perhaps, we have said as much as can be believed at one time.

CARNIVOROUS CATERPILLARS.—It is rash to be dogmatic about the vagaries of animals in the quest of food. Who would expect a parrot to attack sheep, or a spider to catch fish, or a slug to devour earthworms, or a trypanosome to live inside a spurge? And, until recently, if one had been told that some caterpillars were carnivorous, one would have smiled. But Dr. Austin H. Clark has recently published an elaborate account of a considerable number of caterpillars which have given up the usual vegetarian diet and taken to carnivorous habits. He has also suggested in a very interesting way how this change of habit may have arisen.

Among the butterflies there is a family of *Lycaenids*, the members of which are usually small in size, but resplendent in colouring, especially on the upper-surface of the wings, which is sometimes of a beautiful blue, the under-surface being commonly soft grey or brown, with streaks and dots. In many ways the Lycaenid caterpillars tend to be peculiar. Thus in many species the body is broadened out like that of wood-lice; the legs are extremely short and the creatures seem to glide; on the eleventh ring there is a lipped oval opening from which there exudes a sweet juice much appreciated by ants; and from the next ring there may be extruded two tall membranous processes with a crown of tentacles near the summit. It is probable that these processes give off an odour attractive to ants. They are at once

withdrawn when an ant comes near. A keen observer has described two Nigerian forms, somewhat slug-like in shape, but with a minutely bristly margin. In handling one of them he felt in his finger and thumb what seemed like a faint electric shock; this was probably due to the very rapid vibration and grating of the rough cuticle against the skin.

Several entomologists have contributed to the elucidation of the remarkable life-history of the large blue butterfly (*Lycaena arion*), which is not uncommon in the south of England. The female butterfly shows a preference for thyme plants growing on the nests of the common yellow ant (*Formica flava*); and she lays her eggs among the blossoms. There the larvae emerge and feed on the thyme flowers. But after the third moult they become restless and will not eat any more thyme. They also cease to exhibit the cannibalistic tendency that is pronounced in their first three stages. They show an impulse to hide underground.

Experiments at this stage indicate that yellow ants are very strongly attracted to Lycaenid caterpillars. They lick the dorsal gland which secretes droplets of sweet liqueur. The caterpillars pass into the earth near or in the ants' nest, and there they feed on ant larvae, increasing in size prodigiously from about an eighth of an inch to over half an inch, and all this without a moult. The great change or metamorphosis into a beautiful blue butterfly usually occurs in the ant passages, and the winged insect has to find its way to the surface.

In the early morning it is seen tremulously drying its wings among the herbage growing above the ants' nest. There is no doubt that the caterpillars of *Lycaena arion* feed for months on the ant brood; and there is no doubt that the ants appreciate the sweet elixir exuded from these caterpillars. Dr. Clark's particular point is that the story of the large blue, and of others like it, gives us the key to an understanding of the habits of other carnivorous caterpillars, for they all feed either upon the young of ants, or upon material regurgitated by ants, or upon ant-tended insects. The common display of cannibalism must also be kept in mind, as also the background fact that the great majority of the members of the family are consistent vegetarians.

As a study in the evolution of habits, it is very interesting to inquire into some other instances of carnivorous caterpillars. There is a somewhat remarkable Queensland butterfly, called *Lephyra brassolis*, which lays its eggs near the large nest of the common green tree-ant; and the larva has been found inside the nest and has been known to attack the ant grubs. But there is no exudation of elixir in this case; and the observations are not numerous enough to exclude the fortuitous. It is probable, however, that we have here the first step towards a habit.

In Southern Nigeria Mr. Charles O. Farquharson observed two

Lycaenid larvae slowly devouring a family of Coccid insects. In this case it seems that the caterpillars begin by being vegetarians and then turn their attention to coccids which are tended by ants. From this, as Clark points out, it is but a step to half a dozen well-established cases where the caterpillar feeds from first to last on the green-flies, coccids, and other insects which ants keep as domestic animals or as pets. There seems no end to these strange **linkages in the web of life** —caterpillars, ant-guests, and ants all woven together!

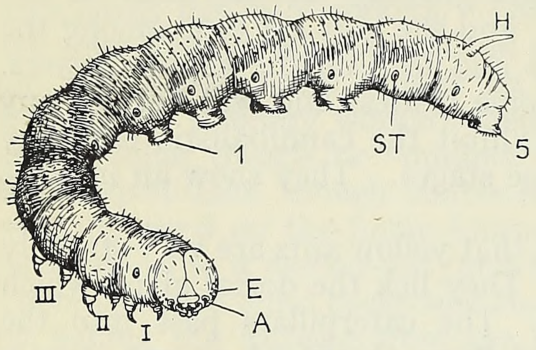


FIG. 123. EXTERNAL FEATURES OF A TYPICAL CATERPILLAR

A, small antennae; E, simple eyes; H, 'horn'; ST, stigma; I, II, III, segments; 1, first pro-leg; 5, fifth pro-leg.

But what seems the climax is the case of a Lycaenid caterpillar which Mr. W. A. Lamborn observed in Southern Nigeria by making a window into the nest of the common tree-ant. He saw a strange sight—a caterpillar with a long neck tapering to a point ending in fine jaws, yet retractile when at rest under a protective hood continuous with the leathery carapace-like covering of the back and sides. As it crawled about, the quaint larva swung its proboscis from side to side, as if in search of food. What was it after? Mr. Lamborn had to peer through the window for forty-eight hours before he saw the answer. The caterpillar did not nibble at the leaves that are bound together to make the tailor-ants' nest; it did not interfere with the dead insects which the ants had stored as food; it did not attack the ant larvae. But to one of the ants it did something almost incredible. It thrust its slender proboscis into the ant's mouth, and kept it there while the ant made movements as if feeding it! When an ant was nursing the proper larvae of the nest there might be seen close by the *social parasite* with its proboscis extended.

What an eerie picture! Biologically regarded, the caterpillar has taken advantage of the ant's instinct to give food to any hungry claimant. But there must surely be some strange bluffing, for we read that when a caterpillar came upon a big ant feeding another ant of a smaller or lower caste, the native would, sometimes at least, retire in favour of the foreigner. We need an appendix to Aesop's *Fables*.

Cases are known where butterflies themselves take advantage of the sugary secretions of green-flies and the like, but there is nothing very surprising in that. The **honey-dew** of the green-fly is not very far away from nectar. Moreover, the bread-and-butter problem does

not count for much in the life of the butterfly. The striking feature is that certain caterpillars—in at least a dozen well-authenticated cases—should depart from the vegetarian regime and become carnivorous, more or less daringly. This seems to us more intelligible if we are right in regarding the caterpillar stage as secondarily interpolated in the original insect's life-history—interpolated as an opportunity for accumulating some savings for the butterfly's love-making and egg-laying.

TENT CATERPILLARS.—A common sight on the Riviera is the large silken canopy spun by the procession caterpillars when they are feeding in companies on the leaves of the Aleppo pine. It is a communal tent and is often as big as one's head, looking like an enormous and very substantial spider's web. When the procession caterpillars (*Cnethocampa pityocampa*) are full-grown they leave their tent and come down from the trees, on which they have often done much damage. They make their way along the ground, sometimes in single file, sometimes in a broad band, seeking for soft soil into which they burrow. During the hot summer they undergo their metamorphosis, and the moths emerge in autumn. As we have said, the caterpillars often do much harm by defoliating the pines, and it is of interest to notice that they are to some extent checked by the larvae of a beautiful beetle (*Calosoma*) that force their way into the silken nest and slay right and left, destroying more than they can devour. How would the world get on without these checks?

In the United States there is a common tent caterpillar (*Malacosoma americana*) of which Dr. Frank E. Lutz of the American Museum has given an interesting description. The egg-masses are laid in midsummer in broad bands round a twig of the wild cherry and covered with a weather-proof varnish. Then the parents die, and it may be mentioned that they are among those insects that do not eat anything after they get their wings. Yet by some sense, probably smell, the mother moth selects for her eggs and her offspring the kind of tree on which she fed when she was a caterpillar. It is probable that a particular odour pulls the trigger of the egg-laying instinct.

Before the cold weather comes, the eggs develop into caterpillars, but these do not break through the egg-envelopes till the young leaves unfold in spring. They remain together, certainly not fasting, and spin a communal tent of silk. After they have finished with feeding, they separate; each goes its own way and finds a safe nook in which to pupate. This brings us back to the moth.

An interesting detail in this devious story is the statement made by Dr. Lutz that the tent caterpillars show a tide-like rise and fall. Every ten or twelve years there is a plague of tent caterpillars; then there comes a check, and for five or six years they are on the downgrade.

Then the tide turns again. One cause of the ebb seems to be a microbe that attacks the eggs; and Nature keeps the balance so well that it hardly seems worth man's while to interfere.

PARTNERS OF GREEN-FLIES.—Leopoldo Vichango, a naturalist working in the Philippines, has made a fresh study of a puzzle that meets us nearer home—the partner-organisms usually found in the Aphids or green-flies which are such a pest on fruit trees, hops, and many different kinds of plants. As every one knows, these injurious insects are extremely successful animals; they multiply in prolific abundance in the warmth of summer, reproducing **viviparously parthenogenetically.** That is to say, what is produced by the mother *Aphis* is a fully formed young *Aphis*, which has no father, for during the summer months no males are present. In spite of bad weather, the severities of winter, and many enemies, green-flies hold their own; and in genial conditions they become a plague. It is probable that their success owes something to their internal partnership or **symbiosis** with minute organisms, which seem to be allied to yeast plants. In a special organ called the '**mycetom**' these 'symbionts' multiply, and in the early stages of the development of the egg, whether parthenogenetic or otherwise, they enter the yolk and establish a partnership with the embryo and with successive stages. They are present in every individual; they do no harm; they do not increase beyond a certain limit; they are sheltered and nourished by their hosts, and they seem to confer some vaguely known nutritive benefit in return. They probably produce digestive ferments that are of use to the Aphids, but this remains uncertain. One of the difficulties blocking the way to more precise knowledge is that no one has been able to get the symbionts to live in artificial cultures outside their hosts. There are some sceptics who doubt if they are micro-organisms at all, but their life-history from egg to adult, and to egg again, as worked out by Vichango and others, is strongly in favour of the idea that they are partner-micro-organisms or symbionts such as are now known to occur in many other insects.

YEASTS AND INSECTS.—Many different kinds of insects feed on material which from an ordinary physiological point of view has a very low nutritive value—dry wood, for instance. We know that some white ants or termites which feed on decaying wood eke out this ascetic fare with **moulds** that they cultivate in labyrinthine 'mush-room frames' made of chewed wood. A quaint fact like this leads us to look with much interest at the suggestion which has been repeatedly made of recent years, that the yeast-cells of various kinds often found in the food-canal of many different kinds of insects may be of value in operating upon and improving the food-material. Baumberger's recent experiments on the fruit-fly (*Drosophila*) point to the conclusion

that when this insect is feeding on fermenting fruit it *must* have yeasts to help it, and it may be that this kind of partnership is of wide occurrence. Yeast-plants may prepare food within themselves and exterior to any host, e.g. by actually building up nitrogenous compounds; they may also help within the body of a host by improving the nutritive value of what has been ingested. It is said that some of the Coccid insects always have internal partner-yeasts, and in one case these are known to penetrate the egg-cell within the mother and to multiply during development. All cockroaches seem to have partner-yeasts. There is no end to the intricacy of the web of life.

GUESTS OF A BRITISH TREE-ANT.—Just as some plants, like vetches and bryony, are ever ready, during their growing period, to attach themselves by their tendrils to other plants, so some animals have a particular gift in the way of linking other lives to theirs. This is very well illustrated among ants, which, as we have noticed, may have guests and pets, partners and even slaves. Part of the reason why so many other creatures become linked up with ants may be that the 'little people' have a firm foothold in the struggle for existence, being dreaded by many much bigger animals. They are thus able to afford some protection to their associates. We are too apt to think of these interesting things as peculiar to warm countries, but this is very far from being true. Mr. Horace Donisthorpe, a distinguished investigator of the ways of ants, has recently studied the associates or '**myrmecophiles**' of an ant, *Acanthomyops* or *Donisthorpea brunneus*, which has been found on various trees in Buckinghamshire and Windsor Forest. A list is given of no fewer than twenty-seven myrmecophiles: seventeen beetles, two *Hymenoptera*, three *Diptera*, one bug, one green-fly, one spring-tail, one spider, and a wood-louse—all found associated with this one kind of ant. It is prodigious! The food of this tree-ant consists chiefly of the sweet juice that overflows from the large green-flies which are kept as cattle. The Aphids generally have the end of their very long proboscis buried in the wood of the branch, and it is difficult to remove them without breakage. 'However large they may be the ants drag and jerk at them unmercifully to make them leave go, so that they can carry them off.'

DISTRIBUTION OF OTHER ANIMALS BY INSECTS.—Just as birds, flying from one watershed to another, may carry small animals entangled on their toes, so some insects distribute other creatures. Many insects scatter mites, and also the tiny Arachnids called '**false-scorpions**' (*Chernetidae*) which hang on by means of their pincers. Water-beetles carry small water-snails and bivalves from one basin to another; thus the large *Dytiscus marginalis* may carry the 'freshwater limpet' (*Ancylus*). The water-scorpion (*Nepa cinerea*) may carry the minute bivalve *Sphaerium* which has closed its shell on the insect's hind-feet.

As Professor Carpenter says: ' In such and numberless other ways do insects come literally into close touch with other creatures, and in the course of their usually brief lives take their share in weaving the vast intertwined complex of vital connections that has been well named the " web of life." '

CLASSIFICATION

Orders of Insects

There is room for difference of opinion in regard to the number of orders that should be recognized in the class Insecta, and there is great uncertainty in regard to the blood-relationships between the different orders. We follow the scheme given in Professor G. H. Carpenter's excellent book, *The Biology of Insects* (1928).

Order: **THYSANURA, BRISTLE-TAILS.**—Primitively wingless insects, with delicate cuticle, long many-jointed feelers, usually compound eyes, old-fashioned mouth-parts, an abdomen of ten segments, some of which usually carry paired appendages, the last two very long, no metamorphosis.

Very widespread is the minute, delicate, white *Campodea staphylinus*, whose name gives the title campodeiform (p. 250) to that type of larva that is seen, for instance, in the large water-beetle, *Dytiscus*. Very like a newly hatched earwig is *Japyx solifugus* that lives among moss by the edges of woods. Gliding on the rocks by the seashore is *Machilis maritima*, famous for its beautiful readily detachable scales. In houses there is a common bristle-tail, *Lepisma saccharina*, popularly called the ' silver-fish.' It reaches a length of nearly half an inch, and is covered with scales which give it a slightly silvery appearance. It feeds on particles of sugar and crumb. A relative found in bake-houses is called *Thermobia furnorum*, and by the bakers ' fire-brats.' A well-known naturalist has likened these ' bristle-tails ' to sardines running on wheels.

Order: **PROTURA.**—Very minute, primitively wingless insects, without feelers, wings, or tail-appendages, but with some abdominal limbs. Some are even without stigmata. Example: *Acerentomon*.

Order: **COLLEMBOLA, SPRING-TAILS.**—Small, primitively wingless insects, with four or rarely six joints in their feelers, and six segments in the abdomen. There are no compound eyes, but merely eye-spots. The cuticle is delicate, sometimes with scales. The first abdominal segment carries a ventral tube, the third a catch, and the fourth a spring, all the three being transformations of paired abdominal limbs. There is no metamorphosis. The leaping, to which they owe their name of spring-tails, is very characteristic.

Examples: On the surface of stagnant pools there are sometimes large numbers of minute spring-tails (*Podura aquatica*), suggestive of floating iron filings, but jerking about. On seashore pools and in chinks one finds *Anurida maritima*, whose tiny body has numerous bristles between which a covering of air collects. The little animals do not become wet even when submerged. *Smynthurus* is a common genus with a well-developed spring and with two curious delicate tubes of uncertain function which can be protruded from the ventral surface. '**Glacier-fleas,**' which sometimes occur in millions on the thawing snow, probably shifting from their winter hiding-places to water, are said to be usually Podurids, e.g. *Achorutes murorum*.

Order: **DERMAPTERA, EARWIGS,** and their allies.—Typically winged insects, but the fore-wings are short horny covers under which the delicate hind-wings are neatly folded fanwise when not in use. There are biting jaws, and the tail-appendages are usually in the form of forceps, which are used in tucking away the wings, and for other purposes. There is no metamorphosis.

The commonest British earwig (*Forficula auricularia*) has an absurdly bad reputation for creeping into human ears, and thence into the brain. The second libel is nonsense; the first is based on a very rare occurrence. Like some other animals, earwigs are fond of narrow passages, where much of the body is in contact with something solid. The forceps are used in folding the hind-wings, in seizing insects, in fighting, and when the two sexes come together. The common earwig can fly. It feeds largely on small insects, but nibbles also at the soft parts of plants. It has a sweet tooth, and is often seen nosing about bee-hives. Just after a moult the earwig

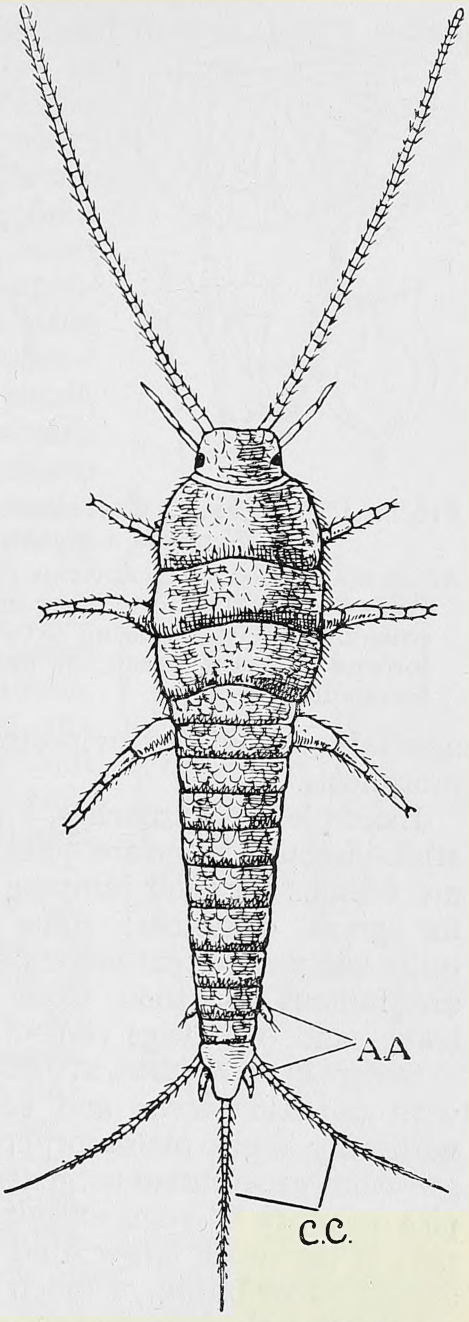


FIG. 124. SILVER-FISH (*Lepisma saccharina*)
AA, abdominal appendages; CC, caudal cerci.

has a whitish colour, and the newly hatched young ones are also very pale. The female guards a clump of eggs laid on or near the surface of the ground, and she is interested in the young ones—miniatures of herself—when they emerge.

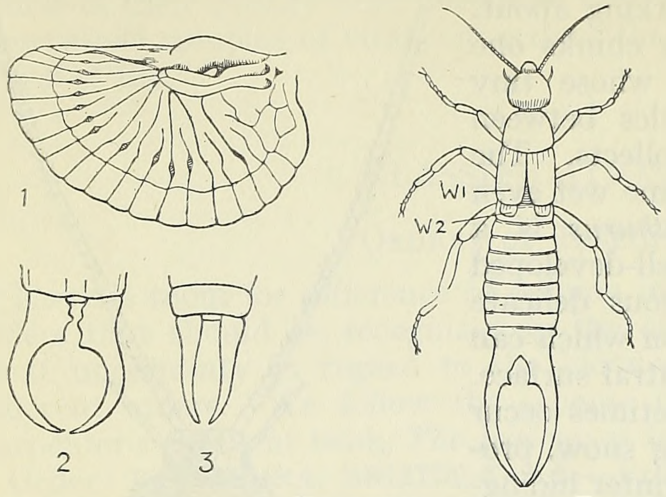


FIG. 125. EXTERNAL FEATURES OF THE EARWIG (*Forficula auricularia*)

Adult male insect with anterior (W1) and posterior (W2) wings. The former are modified into wing-covers. 1, posterior wing extended; 2, posterior forceps of male insect; 3, posterior forceps of female insect.

Order: **ORTHOPTERA, COCKROACHES, LOCUSTS,** and their allies.—Old-fashioned insects with biting mouth-parts and vegetarian diet. The fore-wings are firmer and narrower than the hind-wings. The name refers to the straight course of the main veins or nervures of the wings (*orthos*, straight; *ptera*, wings). Abdominal limbs are represented by tail-appendages and by ovipositors in the female. There is no metamorphosis.

Examples: cockroaches, locusts, grasshoppers, crickets, leaf-insects, stick-insects. Some are quick runners; others are famous for their jumping; locusts can fly for great distances; some *Orthoptera* are quite wingless. Leaf-insects and stick-insects are famous for their close resemblance to leaves and dry twigs respectively.

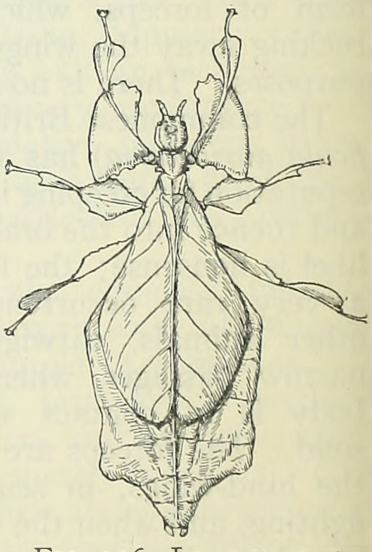


FIG. 126. LEAF-INSECT (*Phyllium*)

Order: **PLECOPTERA, STONE-FLIES.**—Insects with aquatic larvae and aërial adults, yet with only slight metamorphosis. The wings are usually membranous, generally with a complex network of veins except in the posterior part of the much larger hind pair. The jaws are suited for biting, or much reduced. There are long tail-appendages. The submerged larvae breathe by gill-like tufts on the thorax.

The stone-flies are often called *Perlidae*. The larvae are fond of quickly running water, well aërated, and they can stand very low temperatures. Their food consists largely of the aquatic larvae of other insects, such as

may-flies. They themselves are sometimes used as bait for trout, and anglers call them 'creepers.' The adults are weak in flight, in spite of their relatively large wings. *Perla* is a common genus.

Order: ISOPTERA, TERMITES.—Old-fashioned insects, badly called 'white ants,' but not in any way related to true ants, except that both are insects. There are typically two pairs of unfoldable wings with few veins or netted; but many forms are wingless, and winged forms may lose their wings. The jaws are suited for biting; most live on wood. There are usually tail-appendages. Termites are social in habit, and often show several different castes. Perhaps related to them are the *Embiidae*, such as *Embia*, small, delicate, elusive insects, requiring both warmth and moisture. They move about in silken tunnels or galleries in the earth or under stones, and feed on vegetable matter. They are among the most puzzling of insects.

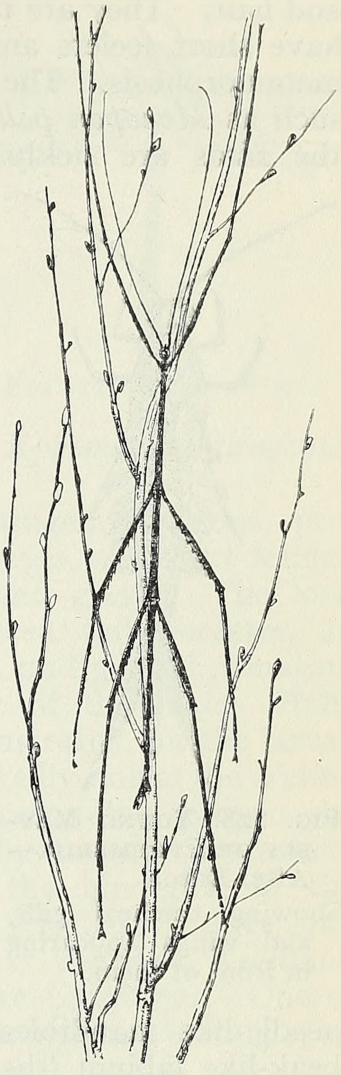


FIG. 127. WALKING-STICK INSECT, AMONG TWIGS

Order: CORRODENTIA, BOOK-LICE, and their allies.—Small soft-bodied insects with biting mandibles and with delicate, membranous, irregularly veined wings or none. In the winged forms the front pair are longer and broader than the hind pair, which is very unusual. There are thread-like antennae. There is a slight metamorphosis.

Book-lice or dust-lice are common but unfamiliar little insects, probably related to termites, often called *Psochidae*. For one or more forms (*Atropos* or *Clothilla*) there are records of sound-production, and this has earned for them the name 'death-watch,' which properly belongs to a small beetle, *Xestobium* (p.290). Many Psochidae have been found preserved inside amber, which is a sort of fossilized resin.

Order: THYSANOPTERA, THRIPS.—Minute, slender, sap-sucking insects; with needle-like mandibles and other mouth-appendages adapted for piercing and sucking; usually with delicate, membranous, narrow wings, fringed with long setae; but some have rudimentary wings or none. There is practically no metamorphosis. Many of these tiny insects frequent flowers and some do much damage. They are sometimes called **black-fly** in contrast to green-fly (Aphids). Examples: *Thrips* and *Euthrips*.

Order: **MALLOPHAGA, BITING LICE.**—Small wingless insects, flat and large-headed, that frequent the skin of birds and mammals. They are not closely related to true lice, and they do not suck blood, but nibble with their biting mandibles at fragments of skin, feathers, and hair. They are rather skin-scavengers than parasites. But they have short feelers and reduced eyes or none. There is hardly any metamorphosis. The common fowl has three distinct biting lice, such as *Menopon pallidum*, and they may become very numerous if the birds are sickly. Dust-baths are useful in keeping them in check. The dog harbours *Trichodectus latus*, to be distinguished from the true dog-louse, *Haematopinus piliferus*.

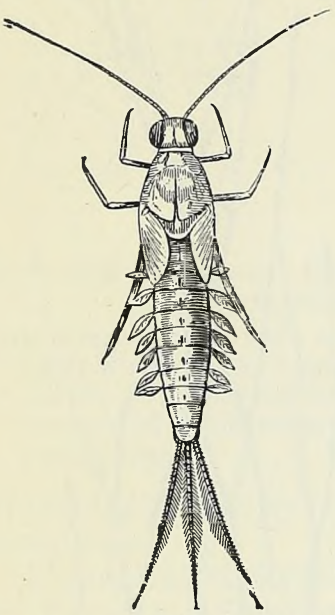


FIG. 128. YOUNG MAY-FLY OR EPHEMERID.—After Eaton

Showing tracheal gills, and wings appearing in front of them.

Order: **ANOPLURA, SUCKING LICE.**—Wingless parasites of mammals, with a tubular suctorial mouth, and with a claw on each foot, suited to clinging to the hair. The cuticle is very thin. There is no metamorphosis. In most cases a particular species of louse is confined to a particular kind of mammal. Thus the elephant's louse is very different from the seal's, and both from the monkey's. Man is infected with *Pediculus capitis* on the head, the closely allied *Pediculus vestimenti* on clothing, and *Phthirius inguinalis* in the region of the groin. They usually indicate a very dirty skin, but they may readily pass from the careless to the careful. The common louse is a carrier of the organism of trench fever, probably a microbe of very minute size not demonstrable microscopically.

Order: **HEMIPTERA or RHYNCHOTA, BUGS.**—A large order of beaked suctorial insects, with needle-like mandibles and maxillae working up and down along a beak-like labium (the fused second maxillae). When the fore-wings are firm compared with the hind-wings, the term *Heteroptera* is used; and this includes the ordinary plant-bugs and water-bugs. In these the beak arises towards the front of the head, and the young ones closely resemble their parents. But when the two pairs of wings are closely alike, and the beak arises far back towards the fore-legs, the term *Homoptera* is used, including cicadas, frog-hoppers, aphids, and the like. In these insects the young ones are often unlike their parents. All of them are sucking insects, the term *Rhynchota* referring to the characteristic proboscis (*rhynchos*, a proboscis) inside which the four stilets work. 'If anything were to

exterminate the enemies of Hemiptera, we ourselves should probably be starved in the course of a few months.'

Order: **EPHEMEROPTERA, MAY-FLIES.**—Delicate insects with short feelers, vestigial jaws, netted wings (the fore pair markedly longer and larger), and three or two long jointed tail-filaments. The life-history shows **half-metamorphosis.** The larvae are aquatic, externally very like bristle-tails, and breathe by platelets or '**tracheal gills**' which are transformed abdominal limbs. May-flies are the only insects in which there is a moult after the wings have developed. Very striking is the sharp contrast between the nutritive sub-aquatic life of the larvae, which sometimes lasts for several years, and the reproductive aërial winged life, which may be all over in one evening. Examples: *Ephemera, Palingenia, Cloëon.*

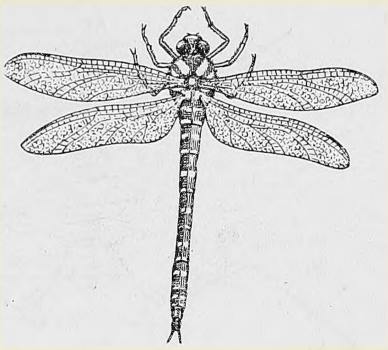


FIG. 129. DRAGON-FLY

Order: **ODONATA, DRAGON-FLIES.**—Strong-winged, vigorous, predatory insects, with powerful biting jaws, large eyes, and short feelers. The wings are netted and glassy. The long abdomen carries unjointed tail-processes, an ovipositor in the female, and genital armature on the second segment of the male. **Half-metamorphosis** is well illustrated, for the larvae are sub-aquatic and markedly unlike the adults. In the large robust dragon-flies proper the aquatic respiration is by means of tracheal tufts on the walls of the hind-gut; in the slender damsel-flies it is effected by three long tail-processes. Examples: *Aeschna, Libellula, Agrion,* and the fairy-like *Calepteryx.* One of the fossils, *Meganeura monyi,* had a wing-span of over two feet.



FIG. 130. DRAGON-FLY AND LARVA CASE

Order: **COLEOPTERA, BEETLES.**—Very successful, usually hard-bodied insects, with strong biting jaws. The firm fore-wings are transformed into sheaths or **elytra** under which the membranous hind-wings are folded when not in use. But these hind-wings are sometimes reduced, even to nothing. There is complete metamorphosis. Out of the egg comes a larva, sometimes campodeiform, hard, active, strong-legged, sometimes a soft-coated worm-like grub with legs reduced or absent. In the quiescent pupa, the wings, which have been developing,

as in all higher insects, from inturned skin-pouches, are turned out and lie free from the body. Examples: scarabees, weevils, ladybirds, fire-flies.

Order: **NEUROPTERA, ALDER-FLIES, and LACE-WINGS.**—Insects with membranous net-veined wings and biting jaws, and larvae usually campodeiform. The alder-flies (*Sialidae*), sometimes used as bait by anglers, are found on vegetation by quiet streams; the larvae live in the water or in damp places. Snake-flies have a long neck; the larvae are voracious terrestrial forms, very clever at wriggling backwards. The ant-lion (*Myrmeleon*) larva is famous for the sand-pit it digs. The beautiful lace-wings or golden-eyes (e.g. *Chrysops*) play an important part in keeping green-flies in check. Many authorities include the dragon-flies and the may-flies in this order *Neuroptera*, but a restricted use is more scientific.

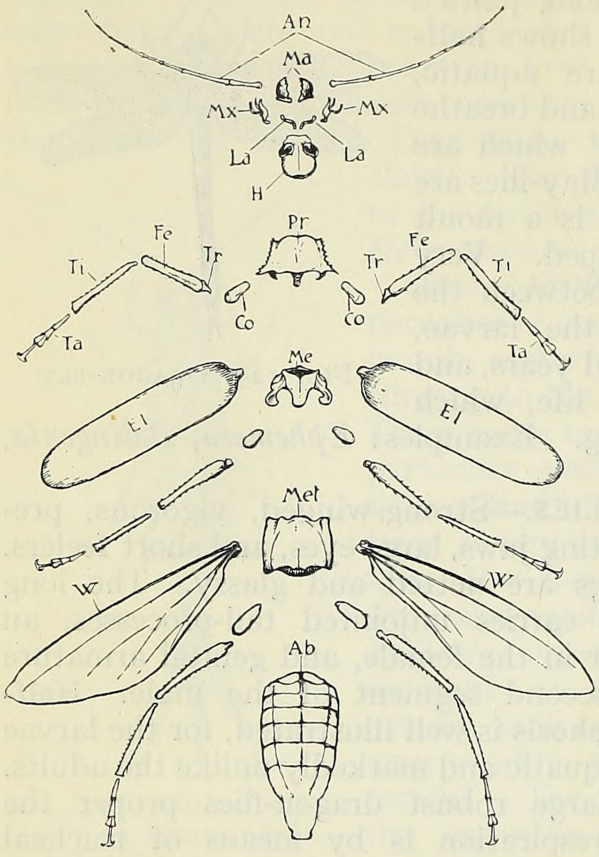


FIG. 131. EXTERNAL FEATURES OF A DISARTICULATED BEETLE

Ab, abdomen; An, antennae; Co, coxa; E1, first pair of wings modified into elytra or wing-cases; Fe, femur; H, head; La, labium or second maxilla; Ma, mandible; Me, mesothorax; Met, metathorax; Mx, first maxilla; Pr, prothorax; Ta, tarsus; Ti, tibia; Tr, trochanter; W, second pair of wings.

Order: **MECOPTERA, SCORPION-FLIES.**—Curious insects in which the head is prolonged into a beak, at the tip of which there is the mouth with the biting jaws. The wings are long and narrow; the females have a long ovipositor. The larvae are of the caterpillar type, but with eight pairs of abdominal pro-legs in addition to the three thoracic pairs. The males have the terminal segments of the abdomen slender and mobile, suggestive of a scorpion's tail. Examples: *Panorpa*, *Boreus*, and the strange *Bittacus*, superficially like daddy-long-legs.

Order: **TRICHOPTERA, CADDIS-FLIES.**—Suctorial insects without mandibles in the adults. There are membranous wings, with minute bristles, many longitudinal veins and few short ones. The hind pair

are shorter and broader. The larvae are the well-known **'caddis-worms,'** which creep about on stones and mud in streams, covered with minute

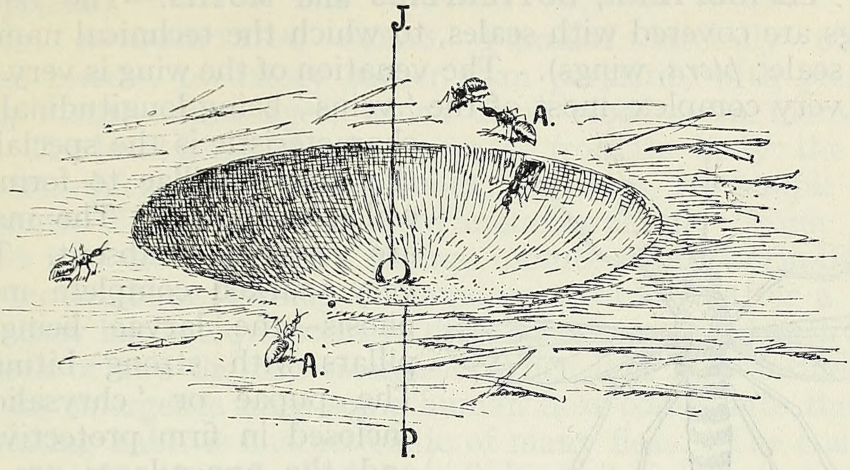


FIG. 132. ANT-LIONS (*Myrmeleon*)
P, pit; J, jaws of larva lying in wait for its prey, e.g. an ant (A).

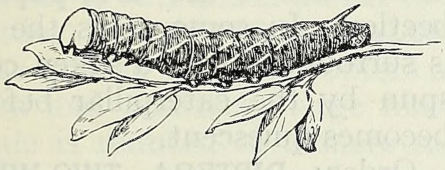


FIG. 133. PRIVET HAWK-MOTH CATERPILLAR

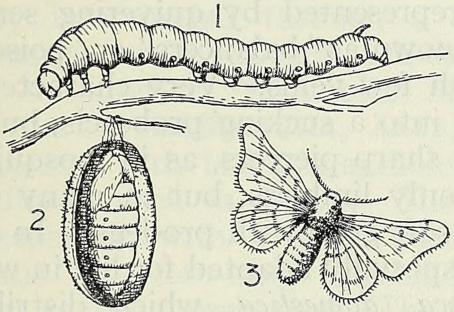


FIG. 134. LIFE-HISTORY OF A MOTH
1, caterpillar; 2, cocoon cut open to show pupa lying within; 3, imago.

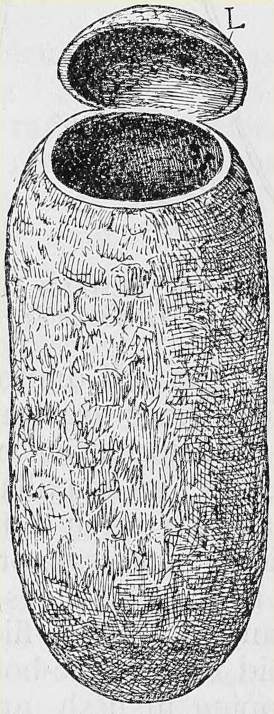


FIG. 135. COCOON OF SILK-MOTH
L, lid.

fragments of stick and the like, or even with tiny pebbles fastened with silk. They have strong mandibles and long gripping legs. They breathe by thread-like gills on the abdomen. Some make well-

fashioned nets into which the current wafts their booty. The pupae rise to the surface in quiet places and allow the winged insects to escape.

Order: **LEPIDOPTERA, BUTTERFLIES and MOTHS.**—The body and the wings are covered with scales, to which the technical name refers (*lepis*, a scale; *ptera*, wings). The venation of the wing is very diverse, but not very complex, most of the 'veins' being longitudinal. Very characteristic is the specializing of the first maxillae to form a long coiled proboscis. The mandibles are vestigial or absent. There is very marked complete metamorphosis—the larvae being caterpillars with strong biting jaws. The pupae or 'chrysalids' are enclosed in firm protective cases, and the appendages are usually cemented closely to the body. These are called 'obtect pupae,' in contrast to the 'free pupae' of beetles. In some cases the pupa is surrounded with a silken **cocoon** spun by the caterpillar before it becomes quiescent.

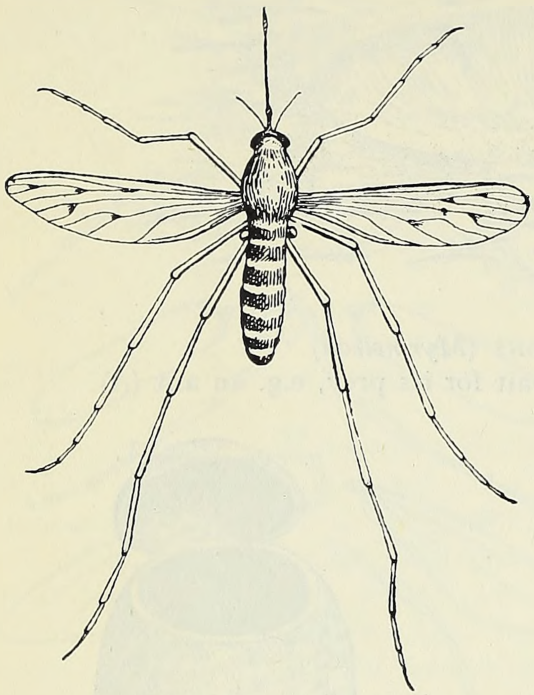


Fig. 136. Female Mosquito (*Anopheles*)

Order: **DIPTERA, TWO-WINGED FLIES.**—A very large order in which the fore-wings only are developed for flight, the hind-wings being represented by quivering sensory *halteres*, like half dumb-bells (also known as 'balancers' or 'poisers'). The fore-wings are transparent, with few veins. Very characteristic is the transformation of the labium into a sucking proboscis, but the mandibles and maxillae often form sharp piercers, as in mosquitoes. The larva is often a maggot, not only limbless, but in many cases practically headless; or it may be a soft grub with pro-legs. In some cases, as in mosquitoes, the larva is specially adapted for life in water.

Examples: house-flies, e.g. *Musca domestica*, which distributes typhoid fever; blue-bottles, e.g. *Calliphora vomitoria*, whose maggots, developing in flesh, are called 'gentles' by anglers; tsetse flies, e.g. *Glossina palpalis*, which distributes sleeping sickness; hover-flies, e.g. *Syrphus*, somewhat bee-like, often seen hovering above flowers in the sunshine; the drone-fly (*Eristalis tenax*), common on dandelion flowers, with '*rat-tail larvae*' that develop in very foul places such as manure-tanks, and can lengthen out a 'tail' with two breathing tubes to a length of four or five inches; besides gnats, midges, harlequin-flies,

crane-flies, and many others. The **malaria organism** (*Plasmodium*) is mostly distributed by the dapple-winged gnat or mosquito (*Anopheles maculipennis*).

Order: **APHANIPTERA, FLEAS.**—Familiar laterally compressed wingless insects, predatory rather than parasitic, with piercing and sucking mouth-appendages, which draw blood from mammals and birds. The head is not clearly separated from the body; the antennae are short, thick, and inconspicuous; the eyes are simple and may be absent. Fleas show complete metamorphosis. From the eggs, dropped into crevices, there emerge minute white worm-like larvae, which move about, feeding on organic particles. After a couple of moults they become quiescent in little cocoons covered with dust, and in a week or two the flea emerges. When it is fully formed it often delays its emergence until some human host comes into the vicinity. This waiting habit is characteristic of many fleas. The common flea of man, also found on the badger, is *Pulex irritans*. In warm countries the germ of the plague (*Bacillus pestis*) is disseminated by various fleas, particularly by *Xenopsylla cheopis*, which carries the microbe from rat to rat, and from rat to man.

Order: **STREPSIPTERA, STYLOPSES.**—Very peculiar insects, parasitic in the interior of Hymenoptera and Hemiptera The male has minute elytra and relatively large hind-wings with radiating ' veins.' The female is reduced to a mere sac. They do not kill their hosts, but develop along with them from stage to stage, so that the larval *Stylops* is found, for instance, in a bee-grub, while the adult Stylops is found in an adult ' stylopized ' bee. The male creeps out and flies about for a short time in a greatly excited way. The degenerate female, apparently inseminated through a projecting extremity, gives rise to numerous larvae which attach themselves to larval insects and burrow into the interior. Examples: *Stylops* and *Xenos*.

Order: **HYMENOPTERA, ANTS, BEES, and WASPS.**—A large order of insects with biting mandibles and the labium suited for sucking up fluids, such as nectar. The fore-wings are the larger; both are transparent, with a small number of little areas bounded by the ' veins '; the fore-wings and hind-wings are linked, so that they act in flight as if they were one. The first segment of the abdomen is joined on to the thorax, and the narrow waist of ants, bees, and wasps is the constricted second abdominal segment. Female Hymenoptera have an **ovipositor** which seems to be a transformation of appendages on the last and second last segments. This ovipositor may become a **sting**, which is therefore confined to the female sex. It is a saw in saw-flies. The larva is usually a soft legless grub, and the pupa shows the wings and limbs of the adult lying nearly ' free,' each covered by a delicate cuticle. Examples: besides ants, bees, wasps, gall-flies, and ichneumon-

flies, all of which have a waist and legless grubs, there are the saw-flies, with no constriction at the base of the abdomen and with larvae of the caterpillar type, though with eight pairs of abdominal pro-legs.

Some Notable Insects

EARWIGS.—One of the crumpled rose leaves of summer—perhaps it is a little more—is a plague of earwigs. This is probably an index of the fine weather and of the consequent multiplication of other insects on which 'forky-tails' chiefly feed. Thus the plague is not to be too much deplored, for earwigs destroy many injurious insects, such as frit-flies and leaf-hoppers, and even the eggs of moths.

It is not denied, however, that earwigs have a sweet tooth, and have a liking for sugary fruits, and delicate flowers and leaves. But from their presence inside a tubular flower we must not hastily conclude that they eat or injure that plant, for they may be after nectar, of which there is often abundance, and they may be simply indulging their constitutional liking for narrow and darkish passages. It is that propensity that has given rise to the popular impression that they are dangerous to man by entering the ears of sleepers. There are a few instances of this, but it is an extremely rare occurrence. The idea of their getting past the drum of the ear is absurd.

Earwigs find shelter in hollow stems and rotting tree-stumps, also in earthworms' burrows and under flat stones lying loosely. Thus a good way of trapping them is to scatter about some pieces of elder branch with the pith pushed out and one end corked up. That is the kind of home they like. On the whole they are light-avoiders, and most energetic in the afternoon and evening. There seems to be only one brood in the year in the case of our commonest species, *Forficula auricularia* (see Fig. 125), and it is as adults that a percentage of them survive the winter, lying in a comatose state in suitable shelter.

Early in the year a mother earwig lays about two dozen eggs, usually in a slight excavation in the ground. They are like tiny yellowish pearls. Out of the egg a miniature earwig bites its way, about a sixth of an inch in length and very translucent. It is almost perfect when it hatches, except that it has at first no wings. It begins at once to feed, and as it grows, it periodically moults its husk or cuticle, using the terminal pincers or callipers in disengaging itself from its cast clothes. In two or three months it is full-grown, and there is no moult after that.

We have seen a brood of earwigs hurry close to their mother when we disturbed the family party, and there is no doubt as to the reality of some measure of *maternal care*, though it seems to have been exaggerated by certain observers. In 1773 De Geer remarked that

it was curious to see how the young earwigs ' crept under the body and between the legs of their mother, who remained very quiet and allowed them to do so. She, as it were, covered them as a hen does her chicks, and they often remained in this position for hours together.'

De Geer also noticed that the mother earwig sat over her bunch of eggs. He concluded in these words: ' So insects of this kind take care, in a way, of their offspring after they are born, and stay near them as if wishing to protect them.'

Some observers have been less fortunate, but M. T. Goe has recently confirmed what the old entomologist stated. He notes that the incubation of the eggs lasts for about a fortnight, and that the young earwigs are often tended for some time by their apparently careful mother. In his illuminating *Biology of Insects* Professor G. H. Carpenter writes: ' A pleasing sight is presented to the naturalist, lifting a partly sunken stone beside a hedgerow in winter or spring, by a female earwig with her eggs or her tiny pale youngsters, already strikingly like her in general aspect, but with the forceps-limbs relatively slender and weak.'

The danger of being too psychologically generous in regard to creatures of low degree may be illustrated by the case of the seashore earwig (*Anisolabis maritima*), which makes a little chamber beneath a log or stone and there deposits her eggs. After being laid they are carefully rolled and cleaned in the mother's mouth — and thereafter they are guarded until hatched. The mother also watches the young ones for a few days, but after they once leave her she disowns them, and will try to eat them if they return. That is to say, her instinct to catch a small moving creature is stronger than the maternal instinct which is passing into abeyance. This fluctuation is very characteristic of **instinctive behaviour.**

Earwigs are among the commonest insects in Britain, yet few people have seen them in flight. Perhaps they run so well that they do not often need to fly. Perhaps they fly more often than we think, for they are least active in full daylight.

Some kinds of earwigs have, indeed, lost their wings altogether, but the hind pair are well developed in our common earwig and are occasionally used in flight. They are like tiny transparent fans, and are tucked neatly away under the anterior pair which form wing-covers.

The insect has been seen using its forceps in opening and closing its minute wings. As few people ever see these structures, which have a somewhat ear-like shape, it seems impossible to suppose that the name earwig is a corruption of earwing. The word earwig means a creature that ' wigs ' or runs into ears, a rare occurrence that popular imagination has been pleased to exaggerate into a habit.

As to the forceps or callipers, they represent a transformed pair of

limbs, which may help in getting rid of the moult, in adjusting the wings, and sometimes in combat and capture. The blades are much curved in the males, almost straight in the females. Among the males of our common earwig there is often a variety with particularly long forceps, for *evolution is going on.*

THE SEVENTEEN YEARS' LOCUST.—One of the most noteworthy insects in the United States is a species of *Cicada,* commonly but improperly called the 'seventeen years' locust.' It is not a locust, but a true bug in the order Rhynchota or Hemiptera, and its technical name is *Tibicina* (or *Cicada*) *septendecim.* Another unfortunate popular name is 'harvest-fly.' In the eastern States the cicada appears periodically in huge numbers, and the females do much damage to deciduous trees, while the males attract attention by their noisy serenading. If there is a notable plague in 1935 there is likely to be another in 1952 in the northern States, and in 1958 in the south, for there are two varieties, differing in the duration of the larval and pupal periods—a difference which may be partly due to differences in the conditions of life, though it more probably indicates a constitutional variation in the rate of development.

The typical life-history of an organism may be represented by an ascending and a descending curve, with a low crest between the upward and the downward slope. It may be compared to an old-fashioned bridge—a Mirza bridge. In a plant, we see the development of the seed, the sprouting, the growing, the leafing, the flowering, the fruiting, the seed-scattering, the withering, and the dying. In an annual plant the ascent and descent of life correspond to spring and autumn; in a perennial plant the seasons are marked by minor ups and downs on the general curve. So in the animal there is a familiar sequence—ante-natal development, tender youth, often a larval period, adolescence, love-making, maturity, parentage, full strength, waning, ageing, senescence, and death.

There is a deep reason why the life-history *must* show an ascending and a descending curve, for there is bound to be an alternation between wear and repair, running-down and winding-up, spending and saving; and, sooner or later, in many-celled animals, the processes of senescence gain on those of rejuvenescence, and the downgrade begins. 'And so from hour to hour we ripe and ripe; and then from hour to hour we rot and rot; and thereby hangs a tale.' But to this general idea of a trajectory we must add a luminous corollary, that in different types different arcs of the curve are lengthened out or telescoped down, often, at least, in adaptation to particular conditions of life. Thus one creature—say an eel—may have a very long youth and a short maturity; whereas a mound-bird telescopes its youth and has a long adult life.

In the periodical cicada what is lengthened out is the underground pre-adult life—the larval and pupal period; and this is but an extreme case of what is occasionally illustrated in other types. Thus the aquatic may-fly larva may remain larval for three or four years, while the aërial adult may have its winged reproductive life restricted to a single evening.

To return to the cicada, the adult taps the branches of trees by means of its needle-like stilets enclosed in a firm beak-like sheath; and its food, which does not seem to be very important, consists solely of liquid sap. The female has a strong, curved egg-laying organ or ovipositor, with which she makes half-inch-long punctures in the outer wood of a twig (often of an oak), and lays in each a double row of eggs. Beside the 'egg-nest' she makes another and another. The leaves above the punctures often wither, and the weakened end of the twig may be broken off by the wind. In his scholarly account of this insect Mr. William J. Gerhard says that a few weeks after a large brood has emerged, tracts of oak woodland appear as though they had been scorched by a forest fire.

The whitish cylindrical eggs are about one-twelfth of an inch in length. Out of each there emerges a pale active larva with strong fore-legs suited for digging, and a beak suited for piercing small roots. It drops lightly to the ground; it burrows, usually for a short distance; it settles beside a small sappy root; it encloses itself in an earthen cell, which it enlarges as it grows; it seems to move about very little; it probably feeds chiefly on the juices of the adjacent root; it moults at intervals of years. When the northern variety is about twelve years old it changes into the first of the two pupal stages. These are unlike those of higher insects in being at first energetically active and in resembling the larvae.

When nearly seventeen years have passed after the subterranean life began, these pupae with one accord move upwards to the surface, and there in many cases they build tube-like chimneys or turrets of clay which rise to a height of two to six inches. There may be, Dr. Gerhard says, twenty-five chimneys on a square foot and nine thousand under one tree. A fine exhibit in the Field Museum in Chicago shows these strange structures very picturesquely. After resting for about a month the pupae leave their turrets and climb on adjacent plants. They undergo a final moult, and this discloses the adult winged insects, still flabby and whitish, but becoming firm and greenish by next morning. In a few days the males are making the air noisy with their whirring and buzzing, their musical instrument being of a unique type (two drum-like vibrating membranes) not found in any other insects. The females are mute, but they are soon busy laying their eggs in the tissues of the twigs. In great contrast to the long

subterranean larval and pupal periods, that of adult aërial life lasts only for four to six weeks.

An anonymous writer in the *Turtox News*, published by the well-known Chicago Biological Supply House, describes at first hand an emergence of cicada '**nymphs**' as the pre-adult forms are termed. ' On quiet evenings the nymphs, as they emerged and crawled up the bushes and trees, produced by the movements of the thousands of insect feet a soft rustling that could be heard throughout the White Oak woods, where most of the nymphs seemed to be congregating.' They climbed up the shrubs, their brown cuticle splitting along the back even as they crawled.

' Soon from the clinging nymph a milk-white adult with wrinkled wings emerged, to leave the abandoned nymphal skin clinging with dead claws to leaf or twig, an empty husk.' Of course, in speaking of moults one should never use the word ' skin,' for no animal could survive being skinned. What is moulted in young insects is the non-living renewable cuticle of chitin—a *product* of the underlying living skin.

A distinguished entomologist has compared the chorus of male cicadas to a combination of the noises of a distant threshing-machine and a distant frog-pond. Perhaps it is a masculine letting-off of steam; there is no convincing evidence that the females hear it at all! But there may be vibration-thrills which pass from insect to insect apart from sound-waves. The cicadas rank among the insects with **half-metamorphosis.**

It does not seem that much harm is done during the years when the young cicadas are feeding on the juices of small roots, but the adult females do much injury in orchards and nurseries both by sucking sap and by their egg-laying. Experts recommend that the adults should be collected in the mornings and evenings when they are sluggish, and that in limited areas there should be spraying of trees with strong kerosene emulsion. Since woodlands tend to be restricted as agriculture spreads, cicadas are on the decrease, and one of the few good things the sparrow does is to devour them. But for many a day this long-lived insect will hold its own.

CADDIS-WORMS.—In the mud of ponds—if the water is not foul—and under the stones in the shallows of slow-flowing streams, and even in the ditches, one finds during the wintry months many resting caddis-worms, which become a little more conspicuous later on when they take to roaming about in search of food. They are the larvae of the rather beautiful, but not very familiar, caddis-flies, dull-coloured insects somewhat like little moths, with many hairs on their wings. Hence they are called *Trichoptera*, which means ' hairy winged '; though some entomologists call them *Phryganeidae* i.e. 'dry-stick-shaped'.

They are often regarded as near relatives of the most primitive moths. When adult they do not seem to do much in the way of eating; the mandibles, as in moths, are mere vestiges or altogether absent. We are not aware that caddis-flies do any harm; they may be seen resting on plants or flying feebly near the water.

In the summer months, the female caddis-flies lay their eggs in gelatinous clumps or ribbons, which sink to the floor of the pool or are moored to water-plants. After a while there emerge the somewhat caterpillar-like larvae, firmly built in front, but very delicate behind. So they proceed to cover themselves with little pieces of stick and stone, or leaf and bark, by which their real nature is camouflaged. They have a high standard of workmanship, fastening the selected materials by means of delicate threads of silk, and usually forming a tubular case. Through the anterior opening, which is the larger, they protrude their strong head and legs, while the soft posterior body is fastened by a couple of hooks to near the narrower hind end of the case. It is not easy without breakage to pull the larva out from in front, for it takes a strong grip of its case; but anglers, who sometimes use big specimens for bait, have learned to prod them out from behind by inserting the head of a pin or something of that sort. The larvae seem to be unwilling to leave their case, which not only affords protection and concealment, but is sometimes of use in keeping them weighted down. For they are thus less likely to be washed away by a current. If we carefully open one of the tubes we may see delicate breathing threads on each side of the body; the animal's movements inside its tube keep up a respiratory current. If we take some home to study—in a soup-plate with some water-weed and débris—we must give them a drip from the tap, for few of them can survive stagnancy. They are mainly vegetarian, nibbling at water-plants and also getting some sustenance from microscopic *Algae*. In captivity some of them may be induced to attack little fragments of raw flesh, and there are some very interesting kinds, with one British representative, which make beautiful nets of silk, fastened with the mouths pointing upstream. These net-weaving caddis-worms differ from the ordinary ones in being sedentary, not rovers, and in being carnivorous, not vegetarian. The device of making a net is a good instance of that instinctive inventiveness in face of which we may well stand amazed.

If any one with a little spare time wishes to engage in an experimental study of animals readily available, we can recommend caddis-worms. They do not cost anything for their keep, and they are not always dying. It would be interesting and scientifically profitable to continue the experiments of Miall, Lutz, and others in regard to the case-making habits. As a rule a particular kind of caddis-larva

keeps to a particular kind of building material—pebbles, pieces of stick, fragments of leaf, fine particles of mud, minute snail shells, and so on. Several build fine grains of sand into spiral shells, which were regarded for a while as new species of snail! Many years ago Professor Miall made the neat experiment of disrobing some caddis-worms and putting them in an aquarium where platelets of mica were the only materials available for building a new case. The larvae used these transparent platelets, and the naturalist was able to study their breathing movements through the glassy walls of the tube. Dr. Frank E. Lutz of the American Museum has recently made similar experiments, and has seen the disrobed larvae making new cases out of sea-urchin spines and out of pieces of bladderwort. There is considerable plasticity, and an interesting point is that some *individuals* are more willing to adapt themselves than are others of the same kind.

As we said at the beginning of this study, caddis-worms rest in winter. When spring comes they become active again—feeding, growing, and moulting. When they are full-grown they become pupae within their closed-up cases, and undergo their great change or metamorphosis. About midsummer the pupa emerges from its case, rises to the surface, pulls itself on to a plant, and undergoes a final moult—disclosing the winged adult.

WHIRLIGIG-BEETLES.—In a quiet pool on a stream we sometimes see little companies of whirligig-beetles, which spend most of their life darting about on the surface of the water. They are very interesting little creatures, and we wish we knew more about them. One of the commonest kinds is called *Gyrinus*, and we have often watched them spinning round one another with great rapidity and apparent ease. They swim on the surface by means of their two hind pairs of legs, which are fashioned into neat paddles. They catch small aquatic animals, living on or near the surface; and one cannot but admire the lightness of their movements. They sometimes dive, but that seems to be usually a reaction to surface disturbance. They have two pairs of eyes, which are very sensitive to light; and recent investigation has shown that their dashes in one direction or another are orientated in reference to different degrees of illumination. They make for brightly illumined patches, and this may be part of the reason for the numbers that are sometimes seen together. They draw to the light, like moths to the candle, in a very automatic fashion. In experimental conditions they dive to the bottom if the only source of light is from below. For the same reason, probably, a swarm breaks up in darkness, for there is then no centre to which they react with unanimity. They swim about anyhow when there is practically no light. The larvae are strange creatures, very unlike beetles, with a row of tiny

mobile **gill-tufts** on each side of the posterior body. Biologists must find out more about whirligig-beetles.

TIGER-BEETLE GRUBS.—In many places the tiger-beetle (*Cicindela*) is not uncommon, about half an inch long and of a bright green colour. It is a beautiful agile creature as an adult insect, but it is more interesting as a grub which burrows in the earth. The grub presses the earth to each side and sinks a shaft, which may be a foot in depth. It is in the habit of turning rapid somersaults, jerking itself forcibly against the walls and pressing loose material into them. The lower part of its head forms a rounded polishing instrument which it uses in plastering the walls of the shaft, which may be vertical, or oblique, or even in steps. By means of hooks on the dorsal surface of one of the posterior rings of its body, the grub fastens itself to the wall of the shaft near the surface, so that its head forms a sort of lid. Dr. Robert Stäger of Berne has described the tunnel-making and plastering in detail, and a still more remarkable activity which it would be interesting to verify. If an inquisitive ant or other small creeping insect steps on to the tiger-grub's head-shield when it is serving as the lid to the shaft, the grub bides its time, and then with a convulsive movement jerks its head and the booty resting on it against the wall of the burrow near the entrance. The head shoots upwards and backwards like a Jack-in-the-box and very forcibly, so that the victim is stunned and broken. The blood of the battered booty is sucked, and the husk is then thrown out of the shaft. Many of the ways of solving the bread-and-butter problem are extraordinarily quaint and subtle.

SACRED BEETLES.—It does not now occur to us to regard a beetle as sacred, but that is partly because our imagination has not kept pace with our increase of knowledge. No doubt we have got rid of some of the ignorant superstition with which the old Egyptians regarded the scarabee-beetle and its strange ways, yet in a way they saw more than we do. They recognized that this common beetle was very remarkable in its habits, and they thought that it might be a *symbol* of truths that are too deep for words. So they carved the irrepressible **scarab-beetles** on their monuments as hints of immortality, and they made amulets of even precious stones skilfully fashioned into their likeness. They did not, indeed, make as many 'scarabs' as are now sold to tourists in Egypt, but they made thousands of them and with loving artistry.

One of these beetles which the Egyptians carved and modelled—and even embalmed—is now known to entomologists as *Scarabaeus sacer*. It is one of the **chafers,** related not very distantly to the cockchafer, and it is common in Mediterranean lands. It was the subject of one of Fabre's most fascinating studies, which remain unsurpassed.

He had an extraordinary flair for getting at the intimate life of insects, not by observation alone, but by the insight of sympathy.

The sacred scarab or scarabee is a compact, strongly armoured beetle, about an inch long, with very powerful legs adapted to burrowing in the ground, and also to kneading and rolling the balls of dung which form its food. The race of scarabees is probably much more ancient than that of cattle or camels, and the habit of utilizing the droppings of herbivorous mammals may be relatively modern. Indeed, there are said to be some scarabees which make balls of earth that is rich in decaying vegetable matter. In any case the scarabees belong to the ranks of **vegetarian scavengers** who keep the surface of the earth free from rottenness.

Their present-day object seems to be to get the balls of dung below the ground into a place where the stuff will not dry up too quickly, and where they can eat it in leisurely continuity, for the story is that they never stop eating till the ball is finished. In all likelihood the burying of the ball or the hauling of it into a burrow is correlated with a relatively arid region, and also with an intensity of struggle that precludes alfresco meals.

There are many lessons for man in the Book of the Play of Animal Life, more lessons than he has yet discerned, far less learned; and one of the clearest is that success rewards strenuous endeavour. As Meredith said: ' The life of ease, it drifts; the sharpened life commands its course.' And what impresses us most in regard to these scarab beetles is that they work very hard for their living. They are strong, indeed, but they are also strenuous and indefatigable. The first task is to knead the dung, say of cattle, into balls, which are often about the size of marbles, and sometimes as large as tangerine oranges.

It is said that the females do most of the work, but it is difficult to distinguish the sexes. The ball is transported in several ways: it may be drawn along as the beetle steps backwards; it may be shoved forwards with the head and fore-legs; the scarab may get on the top of it after the fashion of a performing dog on its big ball; or, fourthly, the strenuous creature may dribble it along with back kicks of its hindmost pair of legs, the head facing away from the direction in which the ball is being rolled. This is very quaint.

The ball is rolled to an excavation already used as a retreat, or it may be rolled to a place where a burrow can be rapidly made. There is more of the instinctive than of the intelligent in the behaviour, for a scarab will exert itself greatly to hoist its ball over an obstacle like a stone, which might be very readily circumvented. Over and over again it will roll the ball to the top of a slope and lose grip at the last moment, so that the treasure rolls back to the foot—the often-repeated performance being extraordinarily suggestive of the task of wicked

Sisyphus, who was condemned to roll a stone to the top of a hill whence it always rolled back again to the bottom.

Two scarabs are often seen helping one another, but they do not pull together very effectively. In some cases Number Two simply hangs on to the ball and does no work. The two apparent partners are often regarded as husband and wife, but Fabre says that they are often both females. When the transport is accomplished and the original housewife goes down below to prepare for the ball, the false helper sometimes trundles it away. Is there a touch of humour in this; or is it the unconscious humour occasionally seen in expressions of instinct?

From the nature of the food it is important that it should be disposed of without too great delay, and the meal is said to be uninterrupted. Fabre watched one eupeptic scarabee who did not stop eating from eight in the morning till eight at night, and then only because there was no more. The meal is often solitary, but the male and female are sometimes seen chewing side by side.

In the hot season the industrious scarabs may lie comatose in their burrow, but in autumn they are in evidence again—a reappearance which the Egyptians likened to a resurrection. At this time they pair and begin to collect material for the future family. After many journeys the material collected forms a mass about the size of a large hazel pear. This is carefully fashioned so that the softer stuff is innermost, and round the egg, which is deposited in the interior, there is a readily digestible, indeed partially digested, nutritive paste. Thus the grub finds food at hand when it is hatched out of the egg-shell. The only danger is that very hot weather may so harden the outer walls of the pear-shaped mass that even the hard-jawed beetle that emerges from the pupa-case cannot gnaw its way out. The Egyptians knew that a scarab emerged from the ball twenty-eight days after the mother had closed it up, and they associated this with the lunar month, which made the beetle more sacred still. What would they have done if they had known, what 'every schoolboy' now knows, of the great change by which the grub is metamorphosed into a beetle?

THE DEVIL'S COACH-HORSE.—A common sight of a summer evening is this long-bodied, dull black, predatory beetle. It rests in its burrow during the day; it hunts at night both on foot and on the wing. Its prey consists mainly of insects, and though it devours beneficial and injurious alike, it is on the farmer's side on the whole and should not be killed. When interfered with it raises its mobile posterior body defiantly, hence the name 'cock-tail beetle'; it also bites strongly with its mandibles; and if the interference continues it squirts out a dark-coloured, offensive secretion from the hind end. The appearance of the beetle (*Ocypus olens*) is peculiar, for the wing-covers or *elytra* are very short. The wings themselves are much folded, but

they are very effective, for the devil's coach-horse can fly quickly and far. Every one knows the adult, but few are familiar with the black larva, which lives a predatory life underground.

BAG-WORMS.—To let the cat out of the bag at once, we may say that bag-worms are peculiar caterpillars, the young stages of certain kinds of moths. They get the name of bag-worm because the caterpillar is concealed in a bag of its own manufacture, which it carries about with it. Many other names refer to this characteristic habit, the best being probably that given to these insects by the Zulus, meaning a creature that carries its house with it. But this name is not available for our use.

Many kinds of caterpillars make protective cases, and it must be admitted that the name 'bag-worms' is used somewhat widely and loosely. It is a practical man's name, and it is applied especially to certain voracious vegetarian caterpillars which damage trees and shrubs, and are marked by their habit of enclosing themselves in 'bags.' They belong to three families of moths—the *Tineids*, which includes the clothes-moths; the *Cossids*, which includes the goat-moths; and especially the *Psychids*, which include the most typical bag-worms. It is interesting to note that these three families of moths are regarded by experts as rather low down in the scale of moths, and, furthermore, that the caterpillars of the other members of these three families, so far as known, are all 'concealed feeders,' burrowing in wood, or inside leaves, or in furs or clothes. The caterpillar of one of our commonest clothes-moths lives in a portable case.

The first step in making the protective case is the formation of a collar round the neck. To this there is then added ring after ring till a conical bag is fashioned, narrowest at the hind end. Different kinds of bag-worms make different kinds of bags, of leaf, and stick, and pod, and bark. One of them, the 'rubbish bag-worm,' uses anything it comes across—'remains of beetles, flat egg-cases of spiders, chips of bark, sticks, dried leaves.' The 'lictor bag-worm' makes a case of small sticks rounded at both ends; the 'grass bag-worm' uses cut pieces of grass-stem; the 'thorn bag-worm' uses very fine particles of leaf or bark, and makes a case like a smooth, greyish-brown thorn; the 'sand bag-worm' makes a bag of sand-grains, like some of the caddis-worms. Some use glue instead of silk to fasten the materials together. They are always very tidy in their habits, keeping the inside of their sack scrupulously clean. Thus the risk of moulds growing or disease-germs flourishing is lessened, though it is not always evaded.

In the majority of caterpillars the **silk-glands** are not brought into full use until it is time to make a cocoon, within which the caterpillar changes into a moth or butterfly. But in most of the bag-worms

spinning is important all through the larval life. The first act of the 'wattle bag-worm' is to lower itself by means of a silken thread from its mother's bag—where it was hatched—on to a leafy branch, or even to the ground. It also makes silk webbing among the leaves; and when the leaves run short it can swing on the end of a long silk thread so that the wind blows it on to another tree. Like many of its relatives, it is very restless at first, and seems forced to do some travelling before it settles down to make its dwelling.

There is a deep reason for this, for in this species and in many other bag-worms the female moths are unable to fly, and never leave the bag which they fashioned as caterpillars and in which they lay numerous eggs—often over a thousand. So the scattering abroad has to be done by the young caterpillars themselves. They have a travelling instinct which in some measure keeps them from settling down just where they were born. Mr. Hardenberg, of the Natal Museum, who tells us of the interesting ways of these creatures, describes a very interesting mode of dispersal. The young caterpillars, still naked, but with a long silk thread, are often caught up by the wind, as small spiders are when they make **gossamer.** They may be carried for miles on their silken parachutes, ' and when the wind dies down and the air becomes calm the bag-worms slowly descend, and fall literally out of the sky on trees, grass, and other objects indiscriminately.' In this way new plantations are infested. The heavy wind-storms may sweep up the young bag-worms even after they have made their bag. It must be queer to see small bags dropping out of the sky.

When the caterpillar has satisfied its roving instinct, which is sometimes stronger than hunger, it settles down to make the bag which masks its real nature. The point about the bag is that it is like anything but a caterpillar. It is often like a dry fruit, or a wilted bud, or a knob of bark, or an encrusting lichen, or like nothing in particular. They often hang down from the branches like cones; they can be enlarged as the caterpillar grows; their attachment, at first loose and temporary, is made strong and permanent when the caterpillar ceases to feed and passes into the chrysalid stage.

There is no good reason for doubting that the disguise saves many a bag-worm from its worst enemy, an insect-eating bird. In the summer, as Mr. Hardenberg shrewdly points out, insects are plentiful, and, ' as the bag-worm withdraws into its bag at the slightest disturbance, it is doubtful whether an insectivorous bird would take much trouble to secure it when other food is plentiful and near at hand. In the winter the conditions are different, and a greater amount of protection is afforded by the bag of withered leaves or dried sticks which blend with the general colour of the vegetation at

that time.' It must be noted that most of the bag-worms pass the winter in the quiescent chrysalid stage, and in the dry vegetation of that season the bags are difficult to see. Before the caterpillar passes into that strange sleep from which it awakens with its dreams realized, it makes an extra silken lining inside its bag, and then it spins a cocoon round itself.

Within this veil the great change occurs; the caterpillar becomes a moth. In the case of the wattle bag-worm, one of the best known, the male moth is active and strong in flight, almost invisible because his wings are transparent. His winged adult life lasts for three or four days, which he spends in searching for his mate. She is a flightless, sluggish insect, remaining inside the bag which she made as a bag-worm, and in which, if all goes well, her children will be cradled. Her grown-up life lasts for about a month.

The story of the bag-worms is very interesting in itself, and it is also of practical importance. In recent years various kinds of bag-worms have been cutting into the circle of human life. Thus, in South Africa, the wattle bag-worm, which infests the black wattle or acacia, has proved very destructive to these valuable trees. Thus it has become necessary for naturalists to study the life-histories and habits of the hungry caterpillars. Life is not for science; science is for life.

THE LIFE OF GNATS.—The common British gnat (*Culex pipiens*) comes a good deal about houses and sheds; it is fonder of indoor places than any other gnat in Europe. The female survives the winter in sheltered places like cellars, and comes forth in May or June to lay her eggs in the water of stagnant pools, rain-water barrels, and the like. These eggs are fertilized by spermatozoa which were received from a male the previous autumn, but no males survive the last mating. About two hundred eggs are glued together in a little boat which cannot be sunk or capsized, and in a few days the larvae come out—popularly known as '**wrigglers.**' In the species we are dealing with the larvae spend much of their time hanging on to the surface film, taking in air by a breathing-tube near the end of the tail and feeding on minute surface organisms, and also on decaying particles. They grow and moult, and after the fourth moult, when two or three weeks old, they turn into ' big-headed ' fasting **pupae.** These have two breathing-tubes on the top of the front part of the body. Within the pupa-husk the great change or metamorphosis occurs, and out of it the fully formed winged insect emerges. There is a critical moment when the cuticle of the pupa splits along the back and the winged insect tries to launch itself into the air without getting its wings wet.

The mating of gnats occurs in the air, and great swarms of buzzing

males are often seen dancing over some raised object like a hayrick. Only the females bite, for the males keep to the old-fashioned food of gnats, namely the sweet juices of flowers and fruit. But the females are keen for draughts of blood—from man, horses, cattle, and even birds—and though it is probably an acquired taste and not indispensable, it seems to serve as a stimulus to egg-laying. A female of the common grey gnat may have three or four broods, and there may be two or three generations in the course of the summer. The numbers are sometimes prodigious and the swarms may look like smoke in the air. The females are irritating, and the bite is often painful, partly because it involves the introduction of a ferment produced by a fungus that lives as a partner in the gnat's gullet. Therefore some people, who are always thinking of everything being adjusted for man's benefit, ask impatiently: What is the use of gnats? In this case, however, the answer is easy. The larval gnats are devoured in large numbers by fishes, thus passing into a higher incarnation. Moreover, both the larvae and the adults form an important part of the food of many kinds of birds. One incarnation follows another, and so the world goes round. Microscopic animal—gnat-larva—fish—waterbird, this is what is called a **nutritive chain.**

FLIES IN AMBER.—Amber is one of the most beautiful non-living things in the world. Its colours are fascinating, both in the translucent and the cloudy forms. It has a pleasant sheen and texture. Moreover, amber has an interesting, elusive fragrance when warmed, strong electrical properties, and great lasting power. And it is not disconcertingly expensive.

Amber is the embalmed essence of the strength of ancient coniferous trees. It is a fossilized resinous secretion, and in a guessing game it would be difficult to decide whether to call it ' vegetable ' or ' mineral.' It is commonest on the shores of the Baltic, where it is washed out of old deposits, but it has a widespread occurrence in small quantities, and usually in small pieces.

There is not the remotest connection between amber and **ambergris,** a fragrant secretion of the food-canal of the sperm-whale. Nor is ambergris to be mixed up with **spermaceti,** which is an oily substance found in cavities of the same whale's skull. The only features that the three things have in common are their commercial value and their origin as by-products of living processes.

The chief scientific interest of amber is not in itself, but as regards the insects and other small creatures for which it has formed a most beautiful tomb. There may be entombed spiders and mites, and other minute animals, besides pieces of leaf and the like, but the commonest enclosures are insects, which have been admired since the time of Martial (died *c.* 102 A.D.). It gives us a glimpse of scientific patience

and carefulness to know that many of the amber-insects have been fully described. Some of them are not known from any other source, and some are peculiarly interesting in being ancestral to types that are living to-day. The evolutionist way of looking at things could be justified from amber alone!

After a stormy night the shore of the Baltic at certain places is sometimes strewn with what might be called 'nuggets' of amber. These have been wrenched by the storm out of nests in the so-called 'blue earth,' which extends outwards on the floor of the shallow sea. This 'blue earth' is a deposit consisting largely of the sediments deposited in the sea at the mouths of ancient rivers. Thus the amber did not arise where it is found; it was carried down as masses of resin from coniferous Eocene forests which once stretched over a large part of the great northern plain of Europe. These primeval forests belonged to the *Eocene* or *Early Tertiary* time, when grass was beginning to cover the earth, and when grazing animals, such as the little ancestors of the horse, were beginning a prosperous career. The old-fashioned mammals were disappearing and modern types were gaining strength. The woods and meadow-lands gave shelter and food to many birds and insects. In short, there was a strong pulse of life at the time, when masses of resin used to float down the rivers from the inland forests.

It is not easy to explain how it became compacted and hardened into its jewel-like quality, but there is no doubt as to its origin; and when we admire a necklace of amber beads with their clear surface, looking so young, and best seen adorning youth, we should remember that they are antiques, millions of years old, far older than mankind. The same is, of course, true of a cigarette-holder or the mouthpiece of a pipe; but that seems to us a somewhat profane use of amber.

Fine forests they must have been in which the amber-making resin oozed out, for the fossil remains indicate pine and spruce, Wellingtonia, cypress, and arbor vitae. There were also flowering trees such as oaks and palms. The nearest present-day analogies of the Eocene forests are in South Florida, where there is the same striking combination of conifer, oak, and palm. There must have been a dense undergrowth with hosts of insects, of which those caught in amber are hardly more than accidental representatives. Perhaps accidental is too strong, since many of the amber-insects are elusive or **cryptozoic** pygmies which are characteristic of crevices to-day and are hardly noticed except by the entomologist.

In a survey of the insects, spiders, and mites found in amber, Dr. Bachofen-Echt, of Vienna, notes that an average year's entomological amber-collecting includes 50 per cent two-winged flies, 10 per cent wingless spring-tails, 8 per cent mites, 7 per cent bugs, 5 per cent caddis-flies, 5 per cent ants and other *Hymenoptera*, 4 per cent spiders,

4 per cent beetles, 3 per cent crickets and the like, and so on in diminishing numbers. There are some great rarities such as moths, caterpillars, may-flies, and centipedes. Numerous relatives of our bot-flies and warble-flies point to an increasing fauna of grazing mammals; and the discovery of a flea, whose living relatives are confined to the mole, points almost certainly to the existence of some such insectivore in the Eocene forest.

Many of the physical or metallic colours are beautifully preserved, and there is a fascination in peering through the amber at the wings and eyes and other parts of the enclosed pygmy. The movements the insect made in trying vainly to free itself are sometimes recorded, and there may be remnants of web beside an overwhelmed spider. Looking into the golden glass the entomologist can see the past, and reconstruct something of its drama.

Some of the amber-enclosures thrill the imagination—a tiny red feather that may have belonged to a woodpecker, a hair which one specialist identifies as a marsupial's and another as a squirrel's. Sometimes the insect's body is broken up and covered with a white material, which has been interpreted as a mould, such as is sometimes seen on dead flies, or as a change in the resin due to an exudation from the decaying body. A quite unique specimen in the museum at Königsberg is a lizard, which was probably dead before it was overwhelmed by the resinous exudation. In some ways most striking is an amberized spider with a number of young ones round about her, and a suggestion of the web.

THE RAT-TAILED MAGGOT.—This quaint creature of the farm is the larva of the somewhat bee-like **drone-fly,** *Eristalis tenax,* that is sometimes seen panting on the dandelions by the side of a sunny road. The fly lays her eggs in very foul fluid, beside a manure-heap or the like, and the larva feeds on the decaying organic matter which it draws into its mouth with the help of a suction-pump. When full-grown it is a greyish, soft maggot, two-thirds of an inch in length, with seven pairs of short-hooked stumps beneath, by means of which it creeps about. But its most remarkable feature, described long ago by Réaumur (1683–1757), is the telescopic tail, which can be lengthened out to reach the surface of the water or whatever the fluid is. The narrower terminal part of the tail can be retracted into or pushed out from the wider lower part; and this also is contractile. At one time the tail may be half an inch long, at another time it may be as much as four inches. Inside the telescope there are two air-tubes or **tracheae** leading to those of the main body, and at the tip there are two openings or **spiracles** by which the air is taken in. There are some recurved bristles at the tip of the tail, which can be spread out on the surface film. They serve to keep the spiracles open, and they sometimes

suspend the larva from the surface. The full-grown larva usually leaves the water and pupates in damp earth. There is a shortening of the body and the tail; two new breathing-tubes grow out on the thorax; the surface of the maggot becomes brownish and hard. Inside this sheath the great change or metamorphosis occurs, as the result of which in eight or ten days an active fly emerges. There are two broods in the year. It may be noted that the drone-fly is not in any way harmful; but we have known of a rare case where the very hardy larva was passed out from a man's food-canal. He had apparently swallowed the eggs along with some water that he foolishly drank from a pool on a golf-course. The occurrence of fly-parasites in man is technically called **myiasis.**

BLOOD-WORMS.—In stagnant and dirty pools in the summer-time, even in rain-water barrels, we sometimes see ' blood-worms,' which are the aquatic larvae of certain gnats or midges, best called **harlequin-flies** (*Chironomus*). Some species have the same red blood pigment, haemoglobin, as we have; and this, as Dr. Isabella Leitch and others have shown, is well suited for utilizing the scarce oxygen in the foul water. It may be noted that insects rarely have any pigment in their blood, and that the insect's blood has not much importance as a gas-carrier, being in the main a distributor of the digested food. Although insects have a contractile blood-vessel or heart, which gives off some arteries anteriorly, there is no closed blood system. The fluid circulates in ill-defined spaces, and here we get an illustration of the use of technical terms, for the nutritive fluid is so different from our blood that it is better to call it **haemolymph** (p. 248). The reason why the ' blood ' system remains poorly developed in insects is doubtless to be found in the very strong development of the system of air-tubes or **tracheae,** which carry air to every hole and corner of the body. The larvae of some species of harlequin-fly have no haemoglobin, and these have to live near the surface of the water, where oxygen is more abundant. In these forms the system of air-tubes is better developed than in the red larvae which burrow in the mud or live in little tubes at the foot of the pool. This is the first remarkable thing about blood-worms, that they have somehow produced haemoglobin and are therefore able to live in water with little oxygen. Their air-tubes are closed, but there are delicate breathing threads or *branchial filaments* growing out from near the posterior end of the body. Into these the air in the water diffuses.

Another peculiarity has been pointed out recently by a Japanese naturalist, Toyowo Matsuki, who has been able to count the heart-beat of these little larvae. Just after the hatching there is an astonishing rate of 300 beats per minute. Matsuki found that the shorter the

body the greater the pulse-rate. As the body-length increased from 5 millimetres to 25 millimetres (i.e. 1 inch), the pulse-rate gradually decreased from about 133 to 61. In the smaller larvae there is a quickening of the quick pulse as the temperature of the water increases. Here then is another peculiarity—a very high pulse-rate.

In the summer-time it rewards one to put a living blood-worm in a watch-glass with water and study it with a good lens or the low power of a microscope. It is a fine instance of intense life, and no one who did not know would suspect that the blood-worm is going to turn into a dancing midge. There is a species called *Chironomus plumosus* that is peculiar in sometimes showing 'phosphorescence' or luminescence. This is remarkable, for there is almost no other case of the occurrence of this phenomenon in animals that have anything to do with fresh water. Every one knows about the luminescence of glow-worms and fire-flies, but these are terrestrial. The vast majority of luminescent animals are in the sea. It would therefore be interesting to hear more about the luminescence of this plumose harlequin-fly. It is exhibited by some adults throughout the body and legs, but not in the wings. Perhaps it is a disease associated with the presence of luminous bacteria such as we see at night on drying fish. In another part of this book something is said about the light that is produced by microbes and the light that is produced by a rapid fermentation in certain organs or tissues of animals (see LUMINESCENCE).

THE STORY OF A SAW-FLY.—Dr. Robert Stäger, of Berne, has described a saw-fly, called *Pontania*, that lays its eggs on the leaves of a kind of willow. Out of the egg comes a small pale-green caterpillar-like larva, and the activity of the larva irritates the living leaf in such a way that it forms a bean-shaped blister, or gall. This gall makes a sort of prison, so that the saw-fly larva does not wander about on the leaf. Thus it is prevented from doing much harm. But it is an eatable prison, and the saw-fly larva chews and chews till only a thin wall is left. Through this it eventually makes a round hole and passes out, seeking the earth.

Having made a little oval hole in the ground, wriggling its body in a curious somersaulting way, the larva spins a felt-work of brownish-red threads of varied thickness, some of which are fastened to small pebbles round about. Little particles of soil are also entangled in the meshes of the spun cocoon, and a continuation of the somersaulting movements makes the cocoon into a neat oval structure. As it is not easy to see how a creature behaves underground, Dr. Stäger removed some of the earth so that part of the egg-shaped cocoon was exposed, and he also cut off a piece of the cocoon-wall. He then had the pleasure of seeing the larva mend the cocoon.

The silk comes out of the mouth, the head is moved rapidly—some-

times twice a second—from side to side, and a felt-work is woven. As the earth had been cleared away there were no particles available for entangling in the freely projecting part that was being mended, so the spinner made some of the strands very firm and filled in the gaps with lighter material. Although the conditions of construction were very unusual, since the new part of the cocoon had to be made outside the earth in which the uninjured part was embedded, the creature finished it off to perfection. After a resting period in the cocoon, during which the architecture of the body is quite changed, the saw-fly emerges and flies away.

The quick movements of the larva's spinning head suggest a rapidly shooting shuttle, a machine. But the fashioning of a large part of the cocoon in quite peculiar conditions, and the suiting of the repairs to the peculiar circumstances, suggest a mind-body at work. No doubt we have here to do in the main with **instinctive behaviour,** not with intelligence, if instinct means an inborn capacity for doing clever things without learning, and if **intelligence** means ability to put two and two together and profit by experience. But what seems to us of great interest in this story of the willow saw-flies is the evidence that a creature which is *mainly* on the instinctive level, marked by a sort of tyranny of routine, may retain a certain plasticity, a power of modifying its behaviour in response to quite unusual messages from the outside world.

Summary: The Wonder of Insect-life

Insects have made themselves masters of their world in ways that man may well envy. Let us gather together some instances of their success, a few of which have been referred to already.

Our admiration of insects is not lessened if we believe that they have gradually arrived at their skilfulness by a kind of inborn inspiration or racially enregistered wisdom which we call **instinct,** which is much nearer to genius than to reason or reflection. Insects are born with ready-made brains, *more born than made,* full of capacities which work if the trigger is pulled. They are hereditarily endowed, likewise, with a fine set of tools, especially in their mouth-parts—a far finer set than can be found in the higher animals. The mouth-parts of a bee, for instance, are extraordinarily perfect instruments, which can be used only in certain ways, suggested by the brain's inborn instincts; whereas our hands are much more all-round tools which can be used in different ways, as intelligent experience demands. To these ways our hands can be trained, but the insect's tools, though doubtless to some extent perfected in the using, are adjusted for

their special work from the very first. They are more 'foolproof' than our hands are.

So the bees rob the flowers and build the honeycomb; the wasps plane fine shavings from the paling and build a hanging house of paper; the termites make mortar and construct great edifices; the tailor-ants sew the leaves together to make a shelter.

What ingenuity insects often show in the securing of food, sometimes for themselves, sometimes for their young! Some ants collect seeds, chew them into a paste, make this into little biscuits, and dry these in the sun. Other ants grow palatable moulds, and still others keep green-flies as cows to be milked. Among the digger-wasps, some of which reach a length of two or three inches, there is every grade, from a random stinging of their prey to a rapid dagger-thrust which paralyses the nervous system. The effects of this are of two kinds: (*a*) a temporary poisoning, which renders the victim inert and incapable of resistance, and (*b*) a permanent injury to the nervous system which leaves the victim blinded and quite stupid.

Some mother wasps feed their grubs on mouthfuls of chewed flesh; and when the mother brings her contribution there is an overflow of salivary juice from the young one's mouth, which the mother licks up with great gusto. It seems to be like an elixir to the mother, keeping her in good courage—a luxury that has become a necessity. We recall, too, the extraordinary story that Fabre tells of the fury-wasp, which makes a dome-like nest of minute pebbles and clay, hangs an egg by a thread from the roof, and puts in from five to ten partly paralysed small caterpillars, which writhe about when touched. When the wasp-grub is hatched, it hangs down from the empty shell of the egg—which is attached to the thread from the roof—and bites a caterpillar from time to time. It would be crushed among them, but it can devour them safely from its ladder.

Admiration has for centuries been aroused by the original way in which the young ant-lion (p. 321) gets its food. This curious insect, distantly related to scorpion-flies, makes a funnel-like pitfall in loose, sandy soil, and buries itself at the foot, with just the tips of its strong jaws protruding. The pits are made by a series of concentric furrows, each deeper and smaller than the one above it. The creature always moves tail foremost, using the body as a plough; it gets the soil on to the top of its head and jerks it out. Small insects coming unawares to the margin of the pitfall tumble down the slope, and before they know where they are, the ant-lion has them in its jaws. The famous naturalist Réaumur (1683–1757) watched a kind of ant-lion which is common in the neighbourhood of Paris, and he tells us that the creature helps its victims down the slope by throwing sand on them with its head. The jaws are large and sharp, and when they grip they do not readily

let go; they have a groove on their under-side, along which the juices of the victim are sucked in. The first part of the name ant-lion refers to the fact that ants are often captured; the second part is not so appropriate, for the creature secures its prey in anything but a lion-like way. Of the full-grown insect little is ever seen; it seems to be shy, and to come out by night.

For solid work take the termitaries which the white ants make, often so strong that one can stand on the dome-like top of one, a yard from the ground. They are sometimes twice the height of a tall man, built by creatures a quarter of an inch long, and are therefore relatively far greater achievements than the Eiffel Tower. At the top there may be a well-aired empty attic, below that a nursery where the young are hatched on shelves, below that a hall supported by pillars of chewed wood, on the ground floor the rooms of the workers, the store-chambers, and a royal chamber where the king and queen are imprisoned. And what shall we say of the cellars, or of the passages that wind about in the earthen walls and open out on the surface?

Or, for delicate building, what can surpass a wasps' hanging nest? It may be as big as one's head, yet how light it is, built of paper; for wasps were the first paper-makers. The material was planed off from palings and bare branches; it was chewed into wood-pulp, which hardened as it was used in fashioning the nest. It was a new idea to have a hanging house, one story suspended from another, and all surrounded with a series of rainproof and windproof envelopes. Inside are hundreds of cradles, but the ventilation is said to be as perfect as the economy of space. Perhaps we cannot understand the wasp's inner spirit, we, who are creatures of intelligence rather than of instinct, but can we fail to admire skilful workmanship when we see it?

They say that for a short distance a bee could outfly a pigeon, and it is certain, at any rate, that the rapidity of wing-beats in bees and flies, and other highly endowed insects, far excels anything else of the kind in the whole animal kingdom. It is not a question of beats per *minute*, but of two hundred or more beats per *second*; and it is this rapidity of vibration that usually causes the hum or buzz. The dragon-fly, hawking other insects on the wing, can still give points to aeroplanes, which is saying a great deal; and one is pleased with the observation of a clever French biologist that one day during the war, when he was bicycling quickly, a wasp flew in front of him for a considerable distance and kept *its face towards his* all the time!

How simply effective is the way many beetles have of extending their heavy wing-covers at right angles to the body and clamping them, so that they serve as planes, greatly lessening the labour of flight, which falls, of course, on the lightly built hind-wings! One of the questions that Socrates asked and answered was how far a flea can jump, and it

is one of the most remarkable of muscular feats. It can leap about two hundred times its own length, an achievement comparable with that of a lion leaping a quarter of a mile!

Let us take a case of masterly movement from our very door, the caterpillars of the large white butterfly, all too common on the cabbages. When they are full-fed and full-grown they leave the host-plant and seek a suitable place in which to pupate, or turn into butterflies. This often means some climbing, and in the climbing they sometimes require to make from below upwards a rope-ladder of silk. The thread is drawn out from the mouth, and by a right and left movement an irregular foothold about a quarter of an inch wide is made for the legs and claspers. A caterpillar one and a half inches long was seen to make 25 rungs of the silken ladder in order to climb its own length. Upon a window-pane, a careful observer tells us, 100 to 145 cross-strands were required to ascend an inch and a half, and some of the caterpillars may ascend 24 feet from the ground. It has been calculated that it would take nearly 5,000 rungs to reach this height, and about 170 yards of silk. The remarkable features here are the building of the ladder from beneath, and the persistence with which the builders obey their impulsion to ascend until they find a suitable place of rest. The higher the caterpillars go the slower they go, and the more tired they appear; but they go on.

From a considerable distance ants can find their way home, and, as we have already noticed, the probability is that they *learn* to do so by utilizing impressions of smell and touch and sight. The numerous experiments that have been made point on the whole in this direction, and they certainly indicate great delicacy of sense. Bees taken from the hive, put into a box, carried for over a mile into the country, and then set free, have been known to make ' a bee-line ' for home in cases where they had known the country before. More experiments are needed, but the probability is that bees, like ants, build up a working knowledge of the lie of the land, and that vision is not necessary for successful homing.

It is well known that the inmates of a hive become aware almost instantaneously if something happens to the queen—if the beekeeper removes her, let us say. It is not a matter of minutes, we are told; the news seems to spread sometimes within one minute. Perhaps the queen has a very distinctive odour, different from the odour of the hive in general. So it is often said, and is not unlikely, that the bee's world is very largely a world of smell, just as a dog's is, whereas our world is mainly a world of sight.

Eye-minded and *ear-minded* creatures we are, so it is not easy for us to get ' on speaking terms ' with creatures like bees—highly civilized as they are—who are probably to a high degree *nose-minded*. But

even suppose we grant that the absence of the queen's odour is at once detected by the workers, as her absence certainly is, how are we to explain the following fact, which we have on the authority of a bee expert of distinction and of shrewd critical faculty?

The beekeeper removes the queen, and there is an immediate hubbub of excitement. But when he takes the queen in his closed hand and holds her against the back of the hive, the excitement subsides almost at once. The news spreads: *The queen is safe.* But how do the workers know? We can scarcely think of an odour-message, for the queen was surrounded by a human hand which must, of course, have a strong scent. Can there be a sound-signal from the queen beyond the range to which our ears are susceptible? Perhaps there is some solution of a simple sort, and this particular instance is but an example of what there are a thousand facts to prove—the extraordinary subtlety of the senses of insects.

In early summer nothing is more familiar on the plants by the wayside than the splashes of froth called cuckoo-spit, which are made by the young of small insects called frog-hoppers. The eggs are laid in crevices in the autumn, they hatch in spring, and the squat larvae, usually green or yellow in colour, proceed to probe the leaves and stems of plants. They get abundance of watery and sugary sap, and it overflows on the body and legs; they work their body up and down, and in a rather complex way whip or knead the sap into foam. There are minute wax-glands near the hind end of the body, and the wax these exude is acted on by a ferment in the sugary sap, and a sort of soap is formed. That is why the frothy masses last as they do in the heat of the sun. An enterprising wasp occasionally picks the frog-hopper out of the foam, but, on the whole, the soap-makers are very safe, though the white splashes are very conspicuous. Eventually the little creature gets wings and flies away.

It is interesting to consider the approaches that some animals make to using tools. One of the wasps makes a burrow and lays her eggs in it, as many do. She stocks the burrow with small caterpillars, bringing one at a time, to serve as a larder for her young ones when they are hatched. As she leaves she closes the mouth of the burrow to keep out intruders. But when the task is finished, and the larder is well provisioned, she closes the door with much more care than before, and in so doing one wasp differs a good deal from another, which is always a hint that we should look out for intelligence. One individual fills up the mouth with a little sand, and finishes it off in five minutes. Another takes an hour, making a fine job of it so that the opening is well hidden, being quite like the surrounding soil. Sometimes, however, the mother has been seen taking a minute pebble in her mouth and hammering the earth with it, so that the blocking

of the entrance is firm and smooth. Nay, more; the creature has been seen laying down her pebble-tool, fetching more earth, and taking up the instrument again.

The tailor-ants, both of India and Brazil, draw leaves together to make a nest, and in so doing they behave in a very remarkable way. The first point is that they work in unison, a number combining to draw two leaves together which no single ant could move. They tug skilfully at the appropriate moment. The second point is that they bind or stitch the leaves together by means of silk threads coming from the mouths of their young ones. A larva is gently but firmly seized in the worker's jaws and is dabbed against the leaf, so that it exudes silk, of which the full-grown ant has none. This is one of the most extraordinary facts in the whole history of animal industry. And one of the little details in the business strikes one's imagination. When the gap between two leaves is too great for a single ant to bridge, five or six ants will unite to form a living bridge. The waist of A is gripped in the jaws of B, who is in turn gripped by C, and so on—a literally living chain, and a very notable gymnastic feat.

One of Nature's anticipations of man is the occurrence of warfare among ants, and it makes one shiver. It is not the everyday individual struggle for existence, this, but competition between great communities or between different species. It is not a sudden frenzy of an excited crowd, for the battle is often long drawn out. Sometimes it ends in a rout with very little mortality. The combatants are thoroughly absorbed in the struggle, yet not far away other workers are pursuing their daily paths. The conflict is intense, says one who has seen it, yet every ant seems to know those of its own party; the result is often nothing. 'We laugh at the ants—the laugh comes back on ourselves.'

We get a truer impression of these things by looking into details, and much is accurately known in regard to the Amazon ant of the Continent. Dr. David Sharp writes: 'The qualities of this ant as warrior are superb. When an individual is fighting alone its audacity is splendid, and it will yield to no superiority of numbers; when the creatures are acting as part of an army, the individual boldness gives place to courage of a more suitable sort, the ants then exhibiting the act of retreating or making flank movements when necessary.'

Now, it is very interesting to find that the jaws of the Amazon species are two sharp poniards, suited for seizing an enemy's head and piercing the brain, but not suited for ordinary work. They are of a kind that occurs in male ants of many kinds, for males do not work, and here we have a gleam of light on the Amazons' peculiar ways. They are slave-keepers which cannot fend for themselves. They will starve without their helpers, which belong to a different race, such as

the brown ant. This securing of helpers is the end of the Amazons' raids; they beat back the brown ants and pillage their nests, carrying off the young. What Dr. Sharp remarks should be remembered—that these young ones are not like fully formed ants when they are deported; they are pupae or larger larvae, 'and they are said to begin working just as if they were in their own houses among their brothers and sisters, and they tend their captors as faithfully as if they were their own relatives. Possibly they do not quite recognize that they are in unnatural conditions, and may be quite as happy as if they had never been enslaved.' The last part of this sentence is curiously like what the defenders of slavery used to say about slaves!

It may be noted that the blood-red ant is the only slave-maker we have in Britain, and that it is much less dependent on its 'helps' than the Amazons are. Its military raids are carried out 'with much tactical ability,' and it seems best pleased with bloodless victories. It carries off the pupae of the conquered race, and these develop into slaves who 'serve the conquerors faithfully, and relieve them of much of their domestic duties.' This fits in well, for the blood-red ant is fond of a good time. It does not sound very moral, all this, but it is desperately ingenious.

The black termite of Ceylon resembles the black wood-ant in colour, in many of its ways, in its nest in a hollow tree, and even in its smell. The soldiers and workers are blind, and yet they go on great excursions in the jungle, marching in armies sometimes several hundred yards long and four inches across, hurrying on hour after hour at the rate of about a yard in a minute, searching for suitable lichen-covered trees on which they feed. The soldiers often stand, head outwards, on each side of the moving file, and there is no doubt that they give audible signals, to which the workers pay strict attention. There are about two hundred soldiers to every thousand workers, and there may be a quarter of a million workers in an army.

The aim of the march is really peaceful, to collect lichens to store, but if they find the tree in possession of the tailor-ants, which are much bigger and more agile than the black termites, they may have to fight. Now, unlike many termite soldiers, those of this particular kind have very small jaws, and the puzzle is how they can fight at all. 'Their tactics are nothing short of extraordinary,' we are told. 'When the tailor-ants draw near, the termite soldiers squirt in their face drops of a viscous secretion, which appears to drive the true ants almost crazy. They drop to the ground and continue for a long time rubbing their faces against stones and débris. The termite soldiers resume their attitude of detached immobility, and the workers go on with their lichen-gathering.'

It is well known that some kinds of ants tend green-flies, stroking

them and licking up the sweet juice which oozes from them. They 'milk their cows,' and in some cases it seems as if they took real care of their cattle. To understand an extraordinary fact like this is still difficult, but we should remember that we are dealing with *social* insects accustomed to a communal life; that it is a characteristic among ants in general that a well-fed individual should, if requested, give food to a hungry one; and that in some ants, as in some wasps, there is a quaint give-and-take in the way of food. There is a sort of 'nutritive exchange'; the young are fed, but they give back an elixir that keeps their nurses in good heart.

These facts make it just a little easier to understand why some ants should have 'domestic animals,' others guests, and others pets —all quaintly suggestive of man's linkages with other creatures.

The difficulty is to stop when one begins to tell of the ingenuity of insects, but perhaps we have said enough to show what a fountain of wonder there is here for all to enjoy. In their food-getting and their movements, in their architecture and their industries, in their self-preservation and their parental care, in their relations with other creatures in war and in peace, insects are wonderful beyond all telling. We must end where we began, by noting that their ingenuities are in great part on a different line from ours, more like genius and less like talent. As Professor Bouvier, one of the shrewdest living students of insects, has recently made clear in his wise book on their mental life: when their behaviour seems to come nearest to our own it is probably furthest away, for the little brain and the big brain are on quite different lines of evolution.

CHAPTER XIV

SPIDERS AND THEIR RELATIVES

A mixed group—Arachnids contrasted with Insects—General characters of Spiders—Webs—Gossamer—Courtship—Parental care—Spiders in the struggle for existence—Spiders in the web of life — Some interesting Spiders — Survey of Arachnids: Scorpions, Mites, etc.—The King-crab.

A MIXED GROUP.—In the great series (or *phylum*) of Jointed-footed Animals or Arthropods there is a mixed group of Spiders, Scorpions, Mites, Book-scorpions, Whip-scorpions, Harvest-men, and so forth, which may be united under the title **Arachnids,** or spider-like. They form a group rather than a class, for they are not very closely akin. Difficulties increase when we try to give a place to: (*a*) the 'Bear Animalcules,' often found in the gutters of houses and among moss; (*b*) the strange worm-like *Pentastomids*, found as parasites in the nasal cavities of dog, python, and some other animals; and (*c*) the quaint Sea-spiders or *Pycnogons*, which are certainly not spiders. We have followed those authorities who bring the King-crab (*Limulus*) also into the Arachnid alliance. What one must avoid is false simplicity, for the fact is that besides spiders, scorpions, and mites, which are not nearly related to one another, there are many distant relatives about which we cannot say much more than that they have more likeness to Arachnids than to any other class or group of animals. Most insects are at once recognizable as insects, but there are many Arachnids that are very puzzling.

ARACHNIDS CONTRASTED WITH INSECTS.

Insects	Arachnids
(*a*) Three divisions in the body.	(*a*) Head always joined to thorax.
(*b*) Usually with wings.	(*b*) No wings.
(*c*) Almost always with feelers or antennae.	(*c*) No antennae.
(*d*) Three pairs of walking-legs.	(*d*) The common number is four pairs.
(*e*) Three pairs of mouth-appendages.	(*e*) Two pairs of mouth-appendages.

The fusion of head and thorax to make a *cephalothorax*, as in the front half of a spider's body, is very characteristic. In mites and ticks the

hind-body or abdomen is also fused, so that the whole animal is, so to speak, one piece, though there is sometimes a movable snout, and one mite (*Opilioacarus*) is actually segmented.

In most cases, instead of the insect's three pairs of jaws or mouth-appendages, there are two pairs, the **chelicerae** and the **pedipalps**, which are used in diverse ways. The hind-body or abdomen is generally, though not always, without limbs in the adult, but there are sometimes traces of abdominal limbs in the embryo, which tell a tale. Their presence means that Arachnids are descended from ancestors that had several pairs of useful legs on the abdomen. Even in the adult there may still be traces. Thus the scorpion has a little bilobed apron over the reproductive or genital opening or openings on the first ring of the abdomen. This lobed platelet seems to be a transformation of a pair of limbs, and the same is true of a pair of sensitive combs (**pectines**) on the next ring. Similarly, in the spider, the **spinnerets**, through which the fluid silk issues in a multiple jet, are transformed abdominal limbs. There are two very important points here. The first is, that ancestral structures may linger on in the embryo, even when they come to nothing in the adult, as is the case with several of the abdominal limbs of the embryo spider and scorpion. The second is, that novel structures have often arisen, in the course of ages, from much older structures. Thus the combs of the scorpion and the spinnerets of spiders are transformed abdominal limbs turned to quite novel uses.

Another difference between Arachnids and Insects is that the former never have the elaborate compound eyes that are so conspicuous in flies, bees, butterflies, and the like. The eyes of Arachnids are almost always quite simple, with one lens in each, instead of many lenses. Of course many insects have simple as well as compound eyes, and a few, like lice, have only simple eyes.

In a common spider, like the house spider, there is a pair of remarkable breathing-organs, like purses with many compartments, which are called **lung-books.** But there are also two or four tubular air-tubes or **tracheae**, like those of insects. Thus a common spider has the insect method of breathing and also a characteristic Arachnid method. Scorpions have four pairs of lung-books, but no tracheae. Active mites have tracheae; sluggish mites breathe through their skin, the most primitive of all methods. Thus we find in Arachnids an interesting combination of a quite novel way of breathing (by lung-books) with an occasional exhibition of the insect method (by tracheae). It seems likely that Insects and Arachnids both sprang from a primitive race of Arthropods that left the water and got on to dry land, and breathed by simple air-tubes or tracheae.

One other contrast may be noted, that there is very little in the

way of metamorphosis in Arachnids. What comes out of the egg of a spider is a miniature of the full-grown spider, and the same is true of scorpions. In mites the state of affairs is not so simple, for the newly-hatched mite has only three pairs of legs, instead of the four pairs that are usually present in the adult, unless it is a form much degraded by parasitism. There is some metamorphosis in the life-history of mites, but the rule for Arachnids is **direct development.**

GENERAL CHARACTERS OF SPIDERS.—The large bird-catching spiders, such as *Mygale*, and the trap-door spiders, such as *Atypus*, have two pairs of lung-books and no tracheae; and the fangs of the deadly nippers (chelicerae) in front of the mouth move vertically, parallel to each other. The more ordinary smaller spiders, such as the garden-spider (*Epeira diademata*) and the house-spider (*Tegenaria domestica*), breathe by a single pair of lung-books and by two or four tracheae; and the fangs of their nippers (chelicerae) move somewhat horizontally towards each other. Most of them weave webs or make snares in the herbage; but belonging to this group there are also hunting-spiders (*Attidae*) that do not do much in the way of web-making.

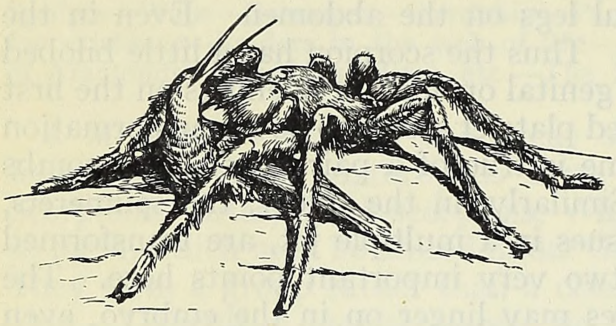


FIG. 137. BIRD-CATCHING SPIDER (*Mygale avicularia*)

(*a*) The body is divided into two regions, the *cephalothorax* and the *abdomen*, neither of them showing in the adult much trace of rings or segments. But the body of the embryo is laid down on a *segmented* or ringed ground-plan, as in all Arthropods. Between the cephalothorax and the abdomen is the narrow waist, through which the food-canal, the nerve-cord, and a blood-vessel must pass.

(*b*) The body is covered with a non-living cuticle of chitin, varying greatly in hardness and colour, and in the number of its setae, which may be popularly called 'hairs.' True hairs, which are built up of many cells remaining alive for a considerable time, are confined to Mammals. Setae are not composed of cells and they have no life in them, though a living nerve-fibre sometimes enters at their base. Since the cuticle is not living it has to be moulted as the spider grows. Thus the young garden-spider moults eight times in its first year.

(*c*) There are six pairs of well-developed appendages. First come the two-jointed **chelicerae** in front of the mouth, each like a pocket-knife with the blade half-open. In the basal joint there is in all spiders a poison-gland, whose duct enters the other joint or fang, and opens by a minute hole near the tip. When the spider clinches its

chelicera in its booty, the last joint shuts down on the basal joint, as the half-open blade of the pen-knife might click back into its sheath, and a drop of poison is injected into the wound. It is a nip, rather than a bite. All spiders are poisonous, and the effect of a nip on an insect is often instantaneously fatal. The poison of the bird-catching spiders is similarly effective on larger creatures, such as birds or lizards. A few of the large tropical spiders give a bite or nip that is troublesome to man, but in most cases a spider is not so formidable as a flea. Nor are spiders aggressive in their relations to man.

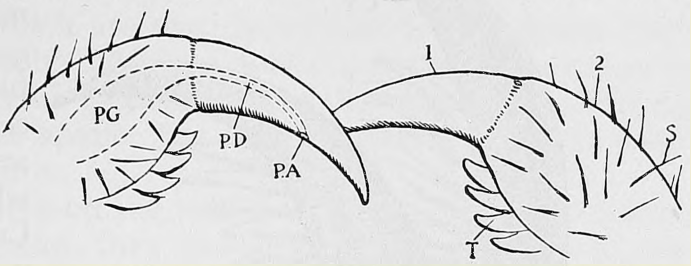


FIG. 138. THE TWO-JOINTED CHELICERAE OR JAWS OF THE SPIDER

1, blade; 2, basal joint; S, bristle or seta; PG, poison-gland; PD, poison-duct; PA, opening of poison-duct; T, comb-like tentacle.

Second come the **pedipalps,** usually six-jointed and leg-like. They help in feeling, compensating in some measure for the absence of antennae; their bases may help in chewing; they are sometimes brandished about when the male is showing off before his desired mate. Strangest of all is the fact that the last joint of the pedipalp becomes swollen in the male spider, and filled with male elements or spermatozoa, which are transferred into the reproductive or genital opening of the female. This is very remarkable, turning a mouth-appendage into a sex-organ. Next come the four pairs of seven-jointed walking legs, each ending in several toothed claws, very useful in gripping roughnesses on the surface over which the spider is creeping. When a spider runs up a wall or creeps along the ceiling with its back downwards, it is holding on to roughnesses by means of its claws. As it has eight legs, it is not likely to fall when one roughness gives way. We have mentioned that the four to six *spinnerets* at the hind end of the body are transformed abdominal limbs. Besides these, the embryo spider has four pairs of rudimentary abdominal limbs that come to nothing.

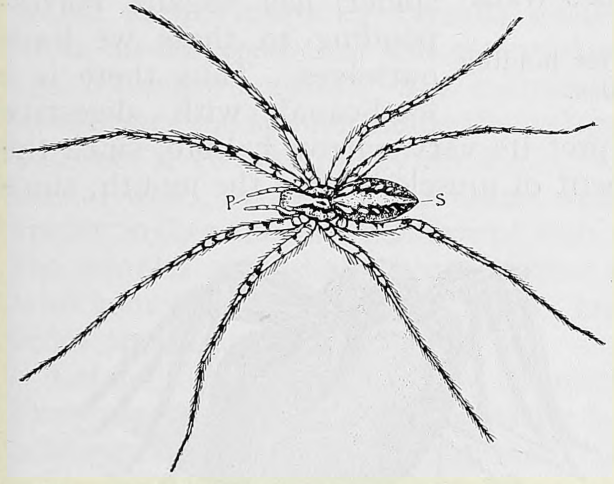


FIG. 139. SPIDER, SHOWING PEDIPALPS (P) AND POSITION OF SPINNERETS (S)

(*d*) The spider's nervous system is of the type found in other Arthropods. That is to say, there is a dorsal brain, connected by a nerve-ring round the gullet with the ventral centres or nerve-ganglia. These ventral ganglia are for the most part fused together in one large centre in the cephalothorax, an interesting repetition of what occurs in crabs among Crustaceans. The spider has a number of small, short-sighted, single-lensed eyes on the top of its head; it has also smell, hearing, and taste; but most important is the exquisite sense of touch which enables the spider to distinguish different kinds of vibrations—of friend or foe, or of booty.

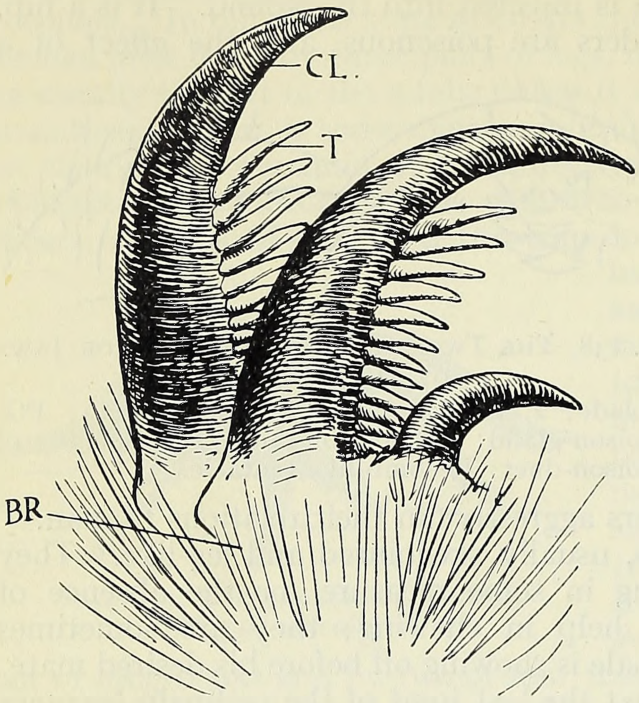


FIG. 140. CLAWS AT TIP OF SPIDER'S WALKING LEG

CL, claw; T, comb-like tentacles for holding on to the web; BR, bristles.

(*e*) Inside its body the spider has organs corresponding to those we have ourselves. Thus there is a food-canal with digestive glands; and it is easy to interpret its very narrow calibre, since the food is fluid, and the development of muscle behind the mouth, since the food has to be sucked in. There is a three-chambered heart, which drives colourless pure blood to the body. There are the respiratory lung-books and air-tubes already mentioned. There are also organs that do duty as kidneys, filtering out the fluid nitrogenous waste. There are also the reproductive organs, ovaries in the female spider, testes in the male. The male opening is far forward on the abdomen, beside the opening of the lung-sacs. The female opening is similarly situated, but there are also two separate openings for two sacs, which receive

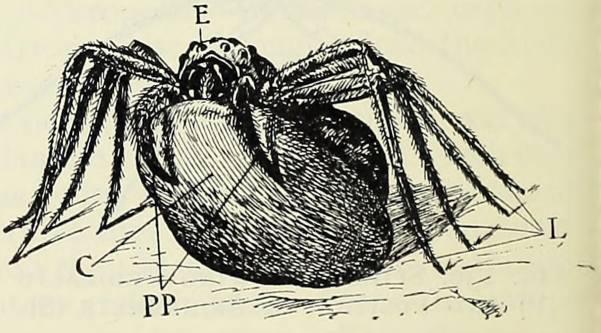


FIG. 141. FEMALE SPIDER (*Dolomedes mirabilis*), WITH COCOON

C, silken cocoon; E, eye; L, legs; PP, pedipalps.

the sperms from the loaded tip of the pedipalps and pass them into the female ducts or oviducts. These arrangements are very complex in spiders, and the relations between the sexes are difficult to understand.

(*f*) Spiders lay eggs, which are usually surrounded by silken bags. These bags or **cocoons** may be hidden in nooks or nests, or they may be carried about by the careful mother. What hatches out of the egg may be called a miniature spider, but it often differs from the adult in little details of structure.

WEBS.—As all spiders live on the juices of other animals, of insects in the great majority of cases, they have to spend much time in capturing their booty. In temperate countries they must be able to lie low without food during the colder weather. While some chase their prey, the great majority rely on snares or webs. In thinking of these we should begin with the **drag-line** which most spiders pay out from their spinnerets when they are in any danger of falling. A tangle of drag-lines amongst the herbage might prove useful in entangling insects, and this leads on to the **snare,** which has viscid threads like a web, but no pattern. A **cobweb,** such as the house-spider makes, is half-way to a true web; it is a sheet or curtain of woven silk, but without much plan. These different stages fade into one another, but a true **web** is an elaborate artifice, with a foundation framework which supports sticky threads glistening with 'insect-lime.' It is often so disposed that the essential part is more or less taut, while the framework admits of a certain amount of 'give' in the wind. Sometimes the spinner holds the web taut by means of a special thread and lets it go when a fly strikes. There are vertical webs and horizontal webs, orb webs and dome webs, and so on; but each kind of spider makes its own pattern of web and no other. Those made by the females are usually more perfect than those made by the males, who sometimes make none at all, but trust to what they can steal from their mates.

Let us take the web of the common garden-spider as a particular example. (1) The spider begins by laying 'foundation-lines' around a selected area, and these are made particularly strong, so that they may be used several times when the more delicate web requires renewal. (2) From the middle of the upper foundation-line the spider drops to the lower one, paying out a line as she sinks, and then pulling it taut. Climbing up this vertical thread, she fixes the centre, and then climbs up to where she began, paying out another line. This is held out on one of the limbs so that it does not entangle with what has been already made. Still paying out, the spider creeps along the upper foundation-line to one end, and pulls the line tight. Going back to the centre again, the spider pays out a thread, descends

to the middle of the lower foundation-line, and then adjusts what may be called the fourth ray. Another and another is formed, all intersecting in the centre, and made alternately in different directions so that the framework is not drawn askew. So ends the second chapter. (3) The spider starts from the centre, and, taking big steps, moves from ray to ray, in a long wide spiral outwards, leaving a strong spiral thread, clamped to each ray at the point of crossing. This is chapter three—the making of the primary spiral. (4) The spider moves on a closer spiral from the circumference inwards, making a viscid thread covered with adhesive droplets. As she works inwards she bites away the primary spiral, which is merely a scaffolding. The secondary spiral is, of course, the essential part of the web on which the insects are caught. It is fastened to each of the rays many times. From the web there is usually a special thread running to the adjacent hole or nest, and it is by the vibrations of this thread that the spider becomes aware of visitors to the web, whether kin, or food, or enemy.

A young spider can make a web of the proper type the first time it tries. It will make a stronger one by and by, but the *pattern* is right from the first. It requires no model, no apprenticeship. Sometimes it works in the dark, yet quite effectively. Thus we say that web-making is **instinctive**: it is the outcome of an inborn or hereditary power of doing effective—apparently clever—things. Practice may make it perfect, but practice is not necessary. Intelligent changes may be made in particular cases, for instance to counteract the wind, but the main activity is on a line different from that of intelligent behaviour. *Instinctive achievements do not require to be learned.*

As to the actual process of spinning, something must be said. The spinnerets, four to six in number, lie just in front of the posterior end of the food-canal. They are movable, and their ends are perforated by numerous (often many hundred) tubes or **spinning spools,** each of which is connected with the duct of an internal silk-making gland. These glands are of different kinds, and the spider can determine which are used, and how many of them. In the garden-spider there are about six hundred separate glands, of five different kinds. We may think of the end of a spinneret as somewhat like the rose of a watering-can, but the openings are not all used at once. The thread that is drawn out or paid out is not composed of many strands; it is a single thread, made from a multiple jet of liquid silk that hardens instantaneously on exposure to the air.

In front of the spinnerets there is often an extra spinning organ in the form of a double sieve-like plate, called the **cribellum.** It is perforated by spinning spools, and from its surface there is combed out a peculiar curled silk. The comb or **calamistrum** consists of a row of stiff bristles near the end of the fourth walking leg. A spider

that has a sieve-like plate will also have a comb, and when two separate structures are linked in this way we say that they are **correlated.**

Threads of silk are used for other purposes besides making drag-lines, snares, and webs. They may be used when a spider lets itself down from a height, and it is a striking sight to see a descending spider begin to coil in the rope and climb up again. It seems to wind the rope round one of its appendages. Another use of the silk is to make a **cocoon** for the eggs and eventually for the young spiders. An insect's cocoon, silken in the silk-moths, is a bag round a single larva, and it is made by the silk-glands which open on the larva's lower lip or **labium.** But the cocoon of a spider is a silken bag surrounding several eggs or young spiders; and it is made by the mother-animal. These cocoons, of diverse colours but most often white, may be hidden away among leaves, such as bramble leaves, which are fastened together by silk threads. Or they may be hung from a twig, or fastened under bark and loose stones. Often they are carried about by the mother-spider herself.

GOSSAMER.—Threads of silk floating in the air or sinking in thousands to the ground are called gossamer. In most cases their story is as follows. On a fine morning with a little breeze, and in autumn especially, many small spiders, of several different kinds, climb on to gate-posts and fences and tall herbs, and adjust themselves with their head to the wind. They pay out threads of silk from their spinnerets—four is a common number—and the breeze helps to draw the threads out. When the grip of the wind begins to exert a little pull on the spider's body, it lets go, and usually turns upside down in so doing. Then it is carried by the wind, supported by its silken floats or parachutes, and may be passively transported from a crowded area to a less crowded area. Careful observers assure us that if the wind falls, the aeronauts can pay out more silk, like a sailor unfurling more sail; and that if the wind rises the spider can wind in some thread, like a sailor furling his sail. When the spiders sink eventually to the ground in large numbers, or when many broken threads gradually fall, there is a shower of gossamer, as was pointed out many years ago by a boy of fourteen, Jonathan Edwards by name, who afterwards became famous as the author of a treatise on *The Freedom of the Will.* It is very remarkable that a thoroughly terrestrial and wingless animal, like the spider, should be able to take aërial journeys, and thus effect a sort of passive migration. Sometimes the spider is carried safely over a sheet of water with the tips of its legs just touching the surface film. On the other hand, it must be admitted that the ' ballooning ' or ' parachuting ' spiders, which are usually small species, cannot in any way command their course. They drift on the wind; they are sometimes borne out to sea.

COURTSHIP.—In many cases there is a marked difference between the male and female spider. The male is usually smaller, sometimes a dwarf compared with the female. In many cases, especially in warm countries, the male is brightly coloured, while the female tends to be dull. This is what is called **sex-dimorphism.** The disproportion is sometimes such as would be observed if a man 6 ft. in height and 150 lb. in weight were to marry a giantess as high as a country church steeple—say 75 to 90 ft.—and 200,000 lb. in weight. Some naturalists are satisfied with saying that it is very advantageous for the male spiders to be small and nimble, for the females are apt to be ferocious and will often kill their suitors. Thus types with pygmy males would be most likely to survive. But there is another way of looking at the facts. It is probable that there is something in maleness that keeps the males small, though we do not know what the 'something' is. Perhaps it is the same undiscovered 'something' that renders the males more brilliant in colouring.

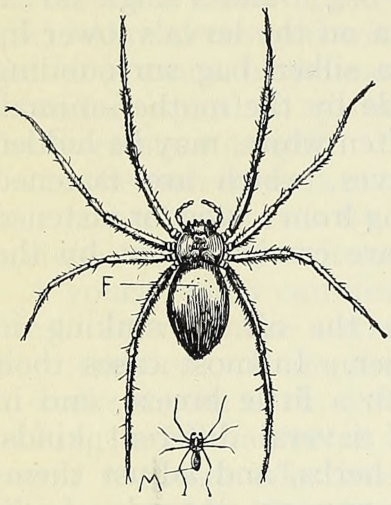


FIG. 142. SEX-DIMORPHISM IN A SPIDER (*Nephila nigra*)
F, female; M, male.

There are three notable features in the courtship of spiders. In the first place, the males are sometimes so combative at the breeding season that they can hardly help fighting when they meet, and their tournaments may continue for hours. The little duellists must be very much alike in dexterity, for there are few wounds or fatalities. Secondly, the males display themselves before the females, sometimes waltzing round and round, sometimes posing and seeming to show off their good points. Thirdly, the female seems at times to lose patience or temper, and rushing at the male, seizes him, kills him, and even sucks his body. One cannot wonder that the male spiders are often very cautious in their love-making. In some cases they make their advances by twirling a thread of the female's web.

PARENTAL CARE.—A few cases are known where the female spider helps the hatched young ones to escape from the enswathing silken cocoon. In a very few cases the mother has been seen bringing food to her offspring. In most cases her maternal care has to do with hiding or carrying the cocoon. When she carries the cocoon about she keeps it clutched under her cephalothorax, and there may be threads of silk mooring it to the hind end of her body. If we try to remove the cocoon, the mother resists strenuously; if it be taken from her she searches for it, guided apparently by smell, for she is

usually very short-sighted. If a pill of bread is rubbed against the silk of the cocoon, the mother-spider may be led to clutch it, being misled by the odour. But she is not long in discovering her mistake. We shall refer later to the maternal care of the trap-door spider and the water-spider.

SPIDERS IN THE STRUGGLE FOR EXISTENCE.—Spiders are hunted by birds, lizards, wasps, and many other enemies. How do they hold their own? In many cases they live very quietly, hiding motionless in a nest near the web; often they are safe enough in their agility and in the ease with which they disappear into holes. It is a pretty sight to see young spiders on a horizontal sheet of silk among the grass; they seem to be learning to move quickly. If the web is disturbed, one of their ways is to drop down instantaneously on silken ropes, so that they are speedily lost in the herbage. After a short time they find their way home.

Many a spider is inconspicuous in its colouring; some are extraordinarily like pieces of bark or lichen; others resemble the petals of certain flowers on which they lurk. Some observers have found reason to believe that certain kinds of spiders seek out situations where they are almost invisible. When their colour hides them from hungry eyes, we speak of **protective coloration.** When they are precisely like some particular object, such as a knot on a twig or a bird's dropping, we speak of **protective resemblance.** Both these self-effacing features may be of great value in the struggle for existence.

Some spiders have a useful power of remaining perfectly still when they are intruded on, and this will save them from those enemies, like frogs, which will only try to catch a moving object (see FEIGNING DEATH). Others again have an uncanny facility in surrendering a leg, and this may also be life-saving (see AUTOTOMY). What has been surrendered may be afterwards replaced by a new growth.

Much of the success of spiders must be due to their skill and artifice. We would use a word like *device*, if it did not too much suggest that the spider planned out the life-saving habit.

What shall we say of that South American spider that makes its web by night or in the early dawn? It snares small insects like male scale-insects, and when the sun rises it draws its net together, and carries it to the nest, where the catch is doubtless appreciated at leisure and away from the dangerous light of day.

But another way in which spiders hold their own in the struggle for existence is simply by taking so much care of the eggs, hiding them away so undiscoverably, or carrying them about so tenaciously. There is no doubt great value, what is called **survival value,** in armour and weapons, in self-effacement and feigning death, in cunning and skill, but there is

as much in securing the safety of the family, and giving them a good send-off in life.

SPIDERS IN THE WEB OF LIFE.—In his picture of what he thought would be a much improved Earth, Emerson included as one of its new amenities the absence of spiders. He had clearly failed to realize that spiders, like wasps, play a very important part in the Economy of Nature by destroying injurious insects. They keep a useful check on the multiplication of small insects like midges. From this point of view there is much to be said for the old superstition that it is unlucky to kill a spider.

If you wish to live and thrive,
Let the spider run alive.

On the other hand there are many animals that feed to a considerable extent on spiders. This is true of some hummers and other birds, of a few mammals like certain monkeys, of some lizards, snakes, and frogs, and of not a few insects such as wasps and army-ants. Some of the ichneumon-flies seek to deposit their eggs in the spider's plump body.

SOME INTERESTING SPIDERS.—The water-spider (*Argyroneta natans*) deserves the first place. This spider, which spends most of its life under water, makes a tent of silk on the floor of the pool, mooring it to stones and the like by silk threads like tent-ropes. Sometimes the shelter is woven among water-weeds. If the tent is on the floor of the pool it is flat to begin with, but the spider proceeds to buoy it up with air. Helped by a special thread, fixed at the bottom and to water-weed at the surface, the spider ascends and entangles air in the hairs of the body. Climbing down the rope, like a drop of quicksilver because of the air-bubbles, it passes under the silken sheet and presses off the air. The air is caught by the silk sheet, and after many journeys the nest becomes like a dome or diving-bell, full of dry air. In this remarkable chamber, dry though under water, the mother-spider lays her eggs, and there her offspring are hatched out. The dry dome may be used as a shelter during the winter, when the spider remains inactive. Young forms sometimes make buoyant houses of the lightly built shells of the water-snail (*Limnaea*). *How does the water-spider escape from drowning?* Part of the answer is that some air remains entangled in the capillary spaces among the setae or hairs. The spider does not get wet, and it carries its breathing air about with it, even from birth. Its long name *Argyroneta* means 'silvery

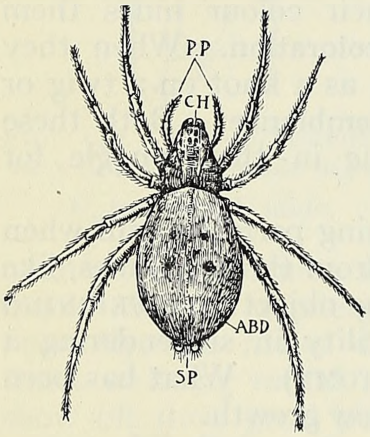


FIG. 143. THE WATER-SPIDER (*Argyroneta natans*) PP, pedipalps; CH, chelicerae; ABD, abdomen; SP, spinnerets.

swimmer,' and the reference is to the silveriness produced by the entangled air-bubbles. In some cases there are little tags of silk among the hairs, and this may help in the entanglement of air. A very unusual feature is that the male is almost twice the length of his mate, and this may have something to do with the placidity and apparent amiability of the female in this species.

Worthy of great admiration are the **trap-door spiders** that sink shafts in the ground in dry sunny places. Several kinds, such as *Cteniza* and *Nemesia*, are common in Mediterranean countries, and were carefully studied many years ago by Mr. Moggridge in the Riviera. The hole is excavated by the strong chelicerae, and the interior of the shaft is made smooth with silk. The opening on the surface is closed with a hinged lid, which helps to exclude intruders. Sometimes this door is merely a loose flap of silk, which was woven and fastened over the entrance, and then cut all round except at the place where the 'hinge' is left. This is what Moggridge called the 'wafer door.' But in other cases the lid is more elaborate. It is made of alternate layers of earth and silk; it has considerable thickness and fits the entrance with precision. It works on a silken hinge and the under-surface has a notch or several little holes by which the spider is able to hold it firmly on the inside. This is what Moggridge called the 'cork door.' Till one's eye gets accustomed, it is difficult to see these trap-doors on the bank by the side of a Riviera road, though one may be standing right in front of half a dozen; and the reason for this inconspicuousness is that the outside of the circular lid, sometimes the size of a franc, is coloured like the immediate surroundings. It may be a circle of reddish-brown earth; it may be in other surroundings an

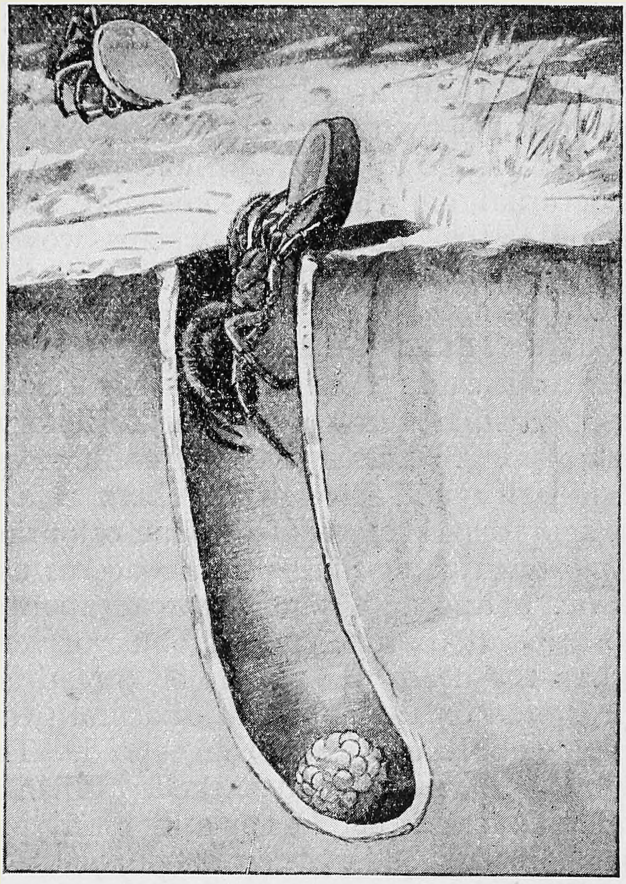


FIG. 144. TRAP-DOOR SPIDERS, SHOWING SECTION OF NEST

equally inconspicuous circle covered with fragments of moss and stick. But it is improbable that the creature of instinct really knows what it is doing, for Mr. Moggridge found that if he removed all the moss round a shaft and took away the door, the new door was covered with moss carried from a little distance. This of course made a conspicuous green door on a bare patch of earth. In some kinds of trap-door nest there is a second door a little below the first; but best of all are the shafts with a blind side-aisle over the mouth of which a door swings downwards. If an intruder, such as a burrowing wasp, gets past the first door, it has then to tackle the second; and if there is a side-passage the spider can go up that and hold its door tight. Trap-door spiders are nocturnal, and there are some shafts whose makers have not yet been found. In some cases a web is woven outside the shaft. Besides being a shelter for the adults, the shaft makes a good hiding-place for the eggs and young ones.

THE SPECIES CALLED 'MAGNIFICENT.'—'In the things of Nature,' Aristotle said, ' there is always something of the astounding '; and this is particularly true of Natural History. The unexpected is always happening. Let us give two recent cases, which are interesting in their similarity and diversity. There is a Queensland spider called *the magnificent*, because of the fine colouring of the female. But it is her way of catching moths that concerns us at present. She hangs down from a line and spins a thread about an inch and a half in length, bearing at the free end a globule of very viscid matter, a little larger than the head of a pin. The thread is held out by one of the front legs, and on the approach of a moth the spider whirls the thread and the globule with surprising speed. The moth is attracted, caught, pulled up, killed, and sucked. When it is touched by the whirling globule it is as helpless as a fly on fly-paper. We may well say of the magnificent spider, '*c'est magnifique.*'

There is another and related spider in South Africa which behaves like the magnificent and yet differently. She is also handsome and large. To a horizontal line she fixes a thread of silk with a viscid globule at the free end, and this is held out by the third or shortest leg. But this spider does not wait for the appearance of a moth and then hurl the globule at it; she whirls it round and round in a horizontal plane. She keeps this up for about fifteen minutes without a pause, then draws up the thread and swallows the viscid globule, for the droplet loses its quality of stickiness on continued exposure to air. After a short rest she makes another globule and repeats the performance. Eventually she catches something. Neither of these spiders makes an insect-catching web—not at any rate in the cocoon-making season, when they were observed.

Survey of Arachnids

Spiders form a well-defined order, but the group of Arachnids, to which they belong, includes or is made to include a great diversity of animals that are not very closely related to one another.

SCORPIONS.—There is no great difficulty with the order of **Scorpions** (*Scorpionidae*), for they have the two pairs of mouth-appendages and the four pairs of walking legs that characterize spiders. They breathe by lung-books which spiders also possess. They are inhabitants of dry and warm countries, insect-eaters, nocturnal, solitary, viviparous, and carry a poisonous sting at the end of the tail. There are about three hundred different kinds.

THE MANNERS OF SCORPIONS.—An interesting study of the large forest scorpion of the Philippines has been recently made by W. Schültze. He deserves congratulations, for scorpions are light-shy creatures, never very keen to show off their habits to the day-light observer. The animal was kept in a museum jar containing about an inch of slightly moist fine river sand on which several pieces of bark were strewn. From the grooves of the bark the creature spooned up considerable quantities of water every day—very unusual behaviour for a scorpion. It fed on crickets and cockroaches which it gripped in its forceps and held off the ground to prevent them from taking grip. It never used the sharp sting that is borne at the tip of the tail, and the observer believes that this particular kind of scorpion (*Palannaeus longimus*) does not use its sting except in conflict with enemies. One must not generalize from this, however, for other kinds of scorpions have been seen bringing their sting quickly forwards to finish off a victim that was struggling recalcitrantly in the grip of the forceps.

The most interesting part of Schültze's study concerns the scorpion's family affairs. On 25th July 1925 eleven young ones were born, miniatures of the parents. All scorpions are viviparous and there is nothing in the way of metamorphosis. In regard to the first point they differ from spiders, which are always oviparous; in regard to the second point they agree with spiders, for the newly hatched spiderling is practically a miniature of the adult. When the young of the Philippine scorpion were first observed, eight were clinging to their mother's back, and three were on the fore-legs and under-surface. Later on there were other births, and the family numbered thirty-four altogether.

The young scorpions are very sluggish and plump; they are glossy creamy-white in colour, but become darker as they grow older. Eight days after birth they exhibited lively contortions, which meant that they were **moulting** their cuticle for the first time. This is an

extraordinary process: the drawing of the muscles through the narrow joints and the unclothing of the whole body so that rapid growth may take place before the new cuticle or husk hardens. The explanation, already referred to, is that in all *Arthropods* or jointed-footed animals the cuticle is non-cellular and non-living, and therefore cannot expand as the creature grows. Therefore it has to be moulted as long as growth continues—a disadvantage attendant on a great advantage. Moulting is the tax that this type of animal has to pay for its very effective armour. In the majority of insects the bitterness of the tax is evaded, for all the moulting is shunted back into the larval period, when the process of disrobing is easier. May-flies are the only winged insects that moult, and that only once, *after* they have attained to the winged stage. Schültze noticed that his young scorpions moulted seven times between 3rd August 1925 and 1st November 1926, which meant a remarkable expenditure of time and energy in a tedious process. The moulting or **ecdysis** is not only tedious; it is apt to involve the breakage of limbs, and it leaves the creature limp and defenceless.

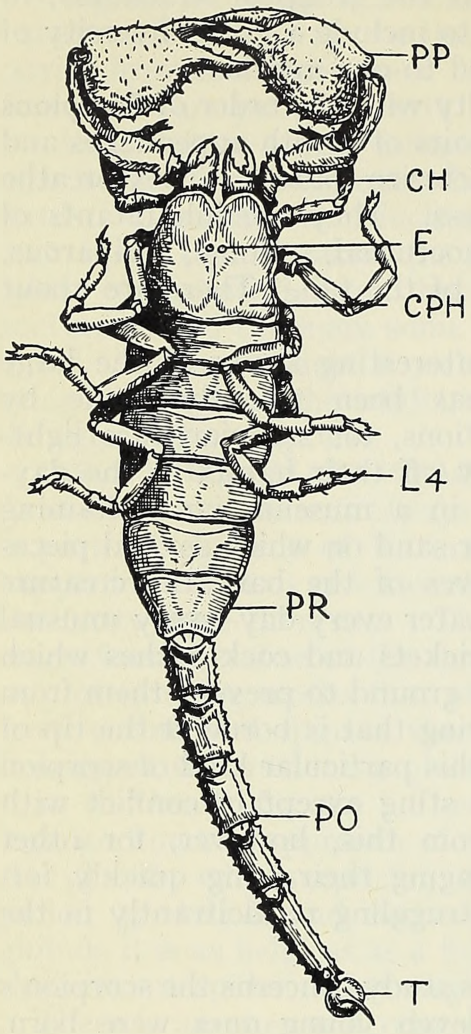


FIG. 145. SCORPION, DORSAL SURFACE

CH, chelicerae; PP, pedipalps; E, median eyes; CPH, cephalothorax shield; L4, fourth walking leg; PR, last (seventh) segment of the pre-abdomen; PO, third segment of post-abdomen; T, post-anal piece or telson, containing the poison-gland.

It has been known for long that the mother-scorpion carries her family on her back, being ' clad in her children,' and that she greatly resents being meddled with. But Schültze adds the interesting information that the mother teaches her young ones how to capture and how to consume their prey. We confess that this report fills us with amazement. Good observers have previously noticed, however, that after the young scorpions have gone off on their own, they sometimes return to the maternal shelter when special danger threatens. In Schültze's case the mother died a natural death on 24th May 1926,

having lived in captivity since 15th June 1925—a good record. One of the young scorpions attained full size in 345 days; eight took 400–464 days; and four had not by that time reached their seventh and final moult. Down to February 1927 none of them had shown any sign of mating.

Most of what we know in regard to the mating of scorpions is due to Fabre, who studied the Languedoc species. Two scorpions stand face to face with their tails raised and their stings touching. The male clasps the female's forceps and walks backwards, she following. The promenade may last for an hour or more, and the end is that the male burrows backwards under a flat stone, and both disappear into the retreat. We may well say ' the end,' for after the consummation the female often devours her mate. This is not quite so extraordinary as it appears at first sight, for scorpions are often cannibalistic. Moreover, after any excited encounter with an enemy, such as a wolf-spider or a centipede, it is *de rigueur* that the scorpion, if victorious, should devour the vanquished. As a matter of fact, scorpions are not great eaters; they subsist mainly on the juices which they suck from their insect or spider booty; and they can endure long periods of fasting.

Scorpions are antiques, for fossil forms occur in the Silurian deposits, hundreds of millions of years old. They are not unnaturally very widespread, for they have had plenty of time to explore. They occur in most countries except in northern latitudes, but they are unrepresented in New Zealand, South Patagonia, and the Antarctic islands. What are the secrets of their persistence? They are well armoured and well equipped with weapons; they are poisonous; they are shy or **cryptozoic,** nowadays at least; they feed mainly on insects, which are usually abundant; they can endure prolonged fasting and drought; they are viviparous, which greatly reduces the juvenile mortality; and they show effective maternal care. So far as we know, the less said about their brains the better; and as to their senses there is little to boast of except in tactility. Their eyes are so simple, distinguishing light and shade rather than form, that it may be doubted if scorpions are ever aware of one another—let alone other creatures—unless there is contact. Like most poisonous animals, they have been interpreted as aggressive, but the very reverse is the truth. They ask to be left alone; they seek to efface themselves; they prefer to walk in darkness. But if the worst comes to the worst they will certainly sting.

We cannot enter on a discussion of the poison of scorpions, which seems to be in some ways peculiar. Thus the experts say that it is not a protein, like snake-venom for instance. It is something ancient and deadly. It may be fatal to man, but this is exceptional. It is

rapidly fatal to insects, which is often to the good. Of interest is the fact that some animals of the desert, like the jerboa, are immune to the scorpion's sting. Nor can a scorpion commit suicide, as has been so persistently alleged. Experiments show that a scorpion is quite immune to injections of scorpion-venom, except in large doses which are quite impossible in Wild Nature.

But to return to the point from which we started, the scorpion tribe has a pedigree going back for hundreds of millions of years, and it is interesting to inquire how it has survived so long. Schültze has given us additional data bearing on this question, and not the least interesting fact is the scorpion's maternal care. It is quaint to think of this including education!

BOOK-SCORPIONS.—Like miniature scorpions, but without the long tail or sting, are the **book-scorpions** or **false-scorpions** (*Pseudoscorpionidae*). They are widespread and common, yet seldom seen by people who are not looking for them. This is partly because they are minute, no British species being over a sixteenth of an inch in length and the largest anywhere hardly a quarter. But another reason is to be found in their retiring habits. They hide under stones and bark, in cracks and crevices, among old books and rubbish, even under the wing-covers of insects; in other words, they are cryptozoic like the true scorpions. Book-scorpions feed on minute insects and mites. They make rounded nests of silk, in which they shelter when moulting or egg-laying or wintering. In some cases the eggs are contained in a sac that remains attached to the mother, and the hatched larvae feed for a while on nutritive fluid secreted into the sac by glands in the mother's posterior body. This is a remarkable instance of **maternal care.** After the larvae have moulted twice, the mother bites a hole in the well-woven silken nest, and the young ones make their exit. There are many different kinds—over a score in Britain. A good example is called *Chelifer*; one of the commonest is *Cheiridium museorum.*

WHIP-SCORPIONS.—Also small and elusive are the **whip-scorpions** (*Pedipalpi*), nocturnal in habit, widely distributed in warm countries, probably for the most part insect-eaters. They have two pairs of mouth-parts and four pairs of walking legs, just as in true scorpions. The breathing organs are lung-books, whereas the book-scorpions have tubular tracheae. The whip-scorpions date from the Carboniferous Period, many millions of years ago. Good examples are *Thelyphonus, Phrynus,* and *Tarantula.* The female of the last-named carries her developing eggs in a bag which is pressed against the under-surface of the posterior body—another instance of **maternal care.**

HARVEST-MEN.—An interesting order is that of the **harvest-men** (*Phalangidae* or *Opilionidae*), which we sometimes see in the evening

stalking amongst the stubble. They can be recognized at once by their extraordinarily long sensitive legs, which are readily broken and readily surrendered. Harvest-men have the usual Arachnid number of appendages—two pairs beside the mouth, and the four pairs of long walking legs; but we can see at a glance that they are not spiders, for there is no waist between the undivided front part of the body and the broad posterior region, which has six rings. The breathing organs are tubular tracheae. The harvesters have no spinnerets, and the eggs are laid without any cocoon under stones or bark. There is occasionally confusion between harvest-men (or harvesters) and 'harvest-bugs' (or 'harvest-mites') which belong to the order of mites. The harvest-men do man no harm; they feed on insects, spiders, and other jointed-footed animals; and they quench their thirst with drops of dew. A common harvester is called *Phalangium opilio*. The order illustrates very well the difficulty of the class Arachnida, for while the harvest-men are obviously near spiders and some other orders, they stand entirely by themselves.

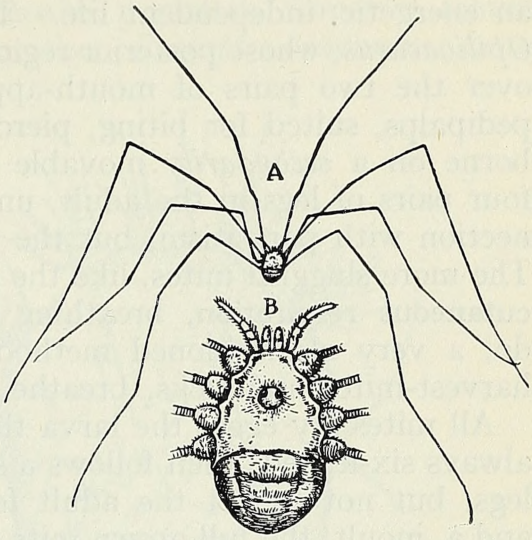


FIG. 146. THE HARVEST-MAN

The small, spider-like 'harvest-men' are noted for their extremely long legs, shown in A, by which they stalk slowly along, avoiding the glare of the day. The broad abdomen, shown in B, is not constricted off from the unsegmented cephalothorax. The pedipalps are like legs. The harvest-men do not trouble us, but feed on small insects.

SOLIFUGAE.—The same is true of the **jerrymanders** or **Solifugae**, somewhat spider-like creatures, at home in many warm countries, such as Africa. There are two pairs of mouth-appendages and four pairs of legs; but the middle region of the body (the thorax) has three separate rings, and the posterior region (the abdomen) has ten clearly defined. They breathe by means of a network of air-tubes or tracheae. Most are nocturnal, but some '**sun-spiders**' like to bask in the sunshine. They usually feed on insects, but can tackle lizards. Many of them rush about at a great pace, and the big ones are much dreaded. They give a shrewd bite with their first pair of limbs or chelicerae, and though they have no poison-glands, the wound may be irritating. It may be that bacteria are introduced into the wound from contaminated chelicerae. British soldiers in Egypt used to have jerrymander fights, pitting one against another. A common Egyptian

form is called *Galeodes arabs*; another is *Solifuga*; about 170 different kinds are known.

ACARINA.—Important in many ways are the **mites** and **ticks,** forming the order **Acarina.** Many of them are parasitic on animals and plants, but many are scavengers, and many of the water-mites live an energetic, independent life. The body is all one piece, except in *Opilioacarus,* whose posterior region or abdomen is segmented. Moreover the two pairs of mouth-appendages (the usual chelicerae and pedipalps, suited for biting, piercing, or sucking) are in many cases borne on a *secondarily* movable snout, or 'capitulum.' There are four pairs of legs in the adult, unless these have degenerated in connection with parasitism, but the young forms have only three pairs. The more sluggish mites, like the cheese-mite and the itch-mite, show **cutaneous respiration,** breathing through their skin as earthworms do, a very old-fashioned method; but the more active forms, like harvest-mites and ticks, breathe by air-tubes or **tracheae.**

All mites lay eggs; the larva that hatches out of the egg is almost always six-legged; then follows a so-called nymph stage showing eight legs, but not as yet the adult features; after deep internal changes and a moult, the full-grown mite emerges. Thus there is some **metamorphosis,** which takes our thoughts back to insects.

In some members of the cheese-mite family the young nymph passes into an interesting quiescent state called **hypopial,** during which it gets carried about by insects and the like. The reason for the mysterious name 'hypopial' is that the modified nymph is so different from the full-grown mites of this family that it was thought to be a separate genus altogether, and was given the name 'Hypopus.' An ordinary cheese-mite is soft-bodied and requires moist surroundings, such as the cavern of a cheese. It could not survive exposure to the sunshine or a journey through the air. But the hypopial stage has a hard upper-surface and fixes itself by ventral suckers to various insects. In a new and suitable locality it loosens its hold, and changes first into an ordinary nymph and then into an adult. This is a good instance of a special arrangement that secures **distribution.**

Interrelations of Mites. Mites are mostly very minute—the size of a millimetre, or one twenty-fifth of an inch, being regarded as large—but the circles of their lives cut many other circles. Dogs and cattle and other domestic animals suffer from **mange** due to species of *Sarcoptes,* which multiply greatly on and in a dirty skin. The disease of **itch** in man is due to *Sarcoptes scabiei.* They 'look like extremely minute pearly-grey tortoises, with four legs directed forwards and four backwards.' The male and female meet on the skin and pair. The male dies after pairing, the female burrows into the skin, and lays her eggs as she goes. She cannot turn or go

backwards, but goes on and on, it may be for months, till she dies, or is smothered. The eggs hatch within a week and the young ones, maturing in about a month, come to the surface and pair. So the infection continues. By actual contact the mature mites may also pass from person to person, or from man to cats and dogs, and other animals. Another of these disagreeable parasites, *Sarcoptes mutans*, causes **scaly leg** on poultry, and another, *Psoroptes communis*, causes

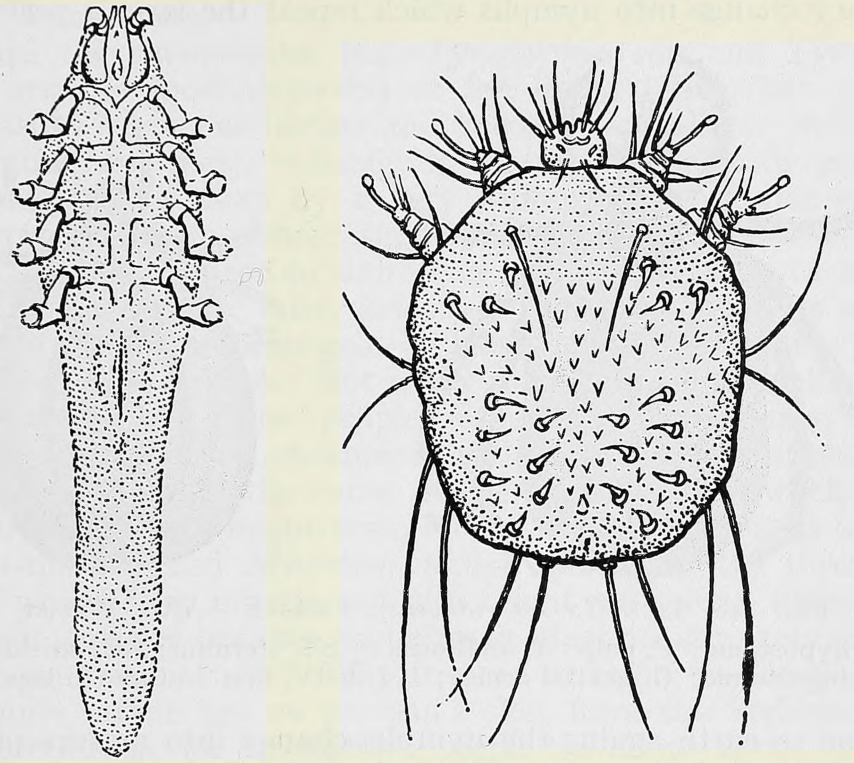


Fig. 147. Itch-mite (*Sarcoptes scabiei*), greatly enlarged

scab on sheep. In a general way it may be said that these mites find their loathsome opportunity when their host's skin is not clean, and when there is some reduction of vigour.

Ticks are large blood-sucking mites, which pierce the skin with their chelicerae and grip firmly by means of a proboscis (**hypostome**) with numerous recurved teeth. They become bloated with blood and are very injurious in warm countries. The members of one family (*Argasidae*) are confined to warm-blooded animals and man, causing irritating wounds because their mouth-parts are fouled with bacteria, but also causing serious disease by introducing virulent unicellular animals (species of the *Protozoa*) of which they are the **carriers.** Thus *Argas persicus* causes a disease in fowls, and *Ornithodorus joubata* in man. In Britain there is a yellow and white tick, *Argas reflexus*, not uncommon about dovecots, which sometimes attacks man.

The other family, the *Ixodidae*, includes many forms, some of which are carriers of the microbes of serious diseases in cattle and other animals. The common sheep-tick (*Ixodes ricinus*) has a complex life-history: the eggs, laid in cracks in the soil, give rise to six-legged larvae which climb on to grass; thence, if they are lucky, they get on to passing sheep, whose approach excites them; they gorge themselves with blood and sink to the ground again, hiding in crevices; there they change into nymphs which repeat the larva's performance

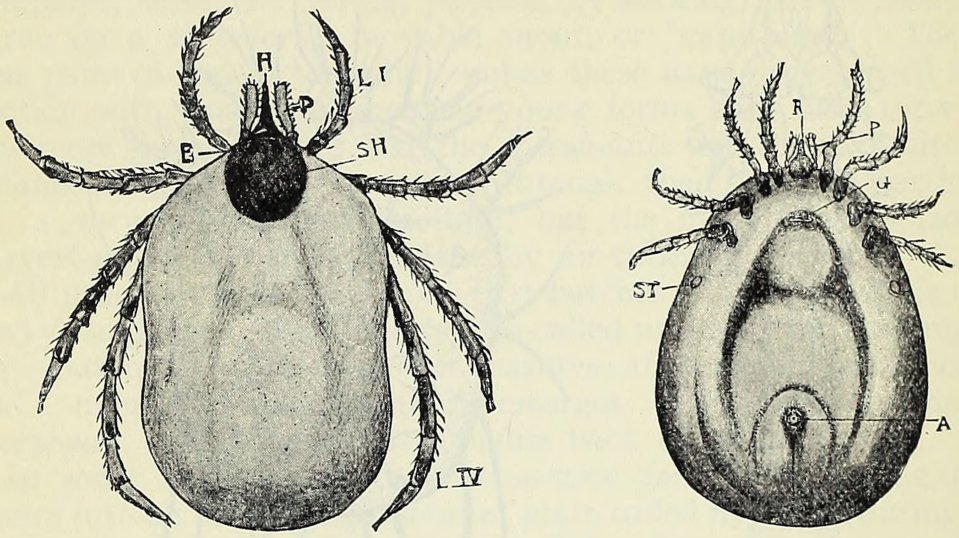


FIG. 148. TICK (*Ixodes riduvius*), FEMALE.—After Wheler
H, hypostome; P, palp; A, anal orifice; ST, sternum; SH, shield for hypostome; G, genital orifice; L I, L IV, first and fourth legs.

and come to earth again; the nymphs change into mature male and female ticks, which get on a third sheep; and, finally, the well-fed, fertilized females drop to the ground and lay eggs. As may be inferred from this story, ticks can stand prolonged waiting, without food or encouragement. Many *Acarina* can remain dry for a long time, and in some cases, while the body dies of starvation, certain cells in the interior combine to form a **cyst**, which may remain latent for many months. For this reason it is often difficult to eradicate mites from badly infested houses or furniture. In short, mites may illustrate **desiccation, latent life,** and **revivification.**

Some of the habitats of mites are curious. If we catch a true black beetle, such as *Geotrupes*, we may find it carrying about half a dozen specimens of a mite called *Gamasus coleopterorum*. The usually vegetarian *Oribatids* are found in decaying wood, or under stones and bark, or among moss. They are all eyeless, but that does not hinder them from hurrying straight into darkness when they are exposed to light. The common parasite of cage-birds is called *Der-*

manyssus avium, and one of the freshwater mites called *Atax* lives inside the pond-mussel. There is a mite at home in the bronchial tubes of seals, another in the air-tubes of the honey-bee, and another *inside* the feathers of birds, feeding on the pith of the quill. There is a family of *Halacaridae* whose members are all marine, creeping about on seaweeds and zoöphytes. So we might continue, but enough has been said to show how mites have explored all sorts of habitats and found a living there.

Perhaps the cheese-mites (e.g. *Tyroglyphus siro* and *Tyroglyphus longior*) are the most degraded of free-living mites, but many of the parasites have gone further and become worm-like. Such is the follicle-mite (*Demodex*), common in the hair-follicles in mammals, and represented in man by a very widespread worm-like creature, *Demodex folliculorum*, whose slightly projecting anterior end forms what is called a **blackhead** on man's face and on other parts of the body. A vegetarian worm-like mite, *Eriophyes ribis*, with the legs uniquely reduced to two pairs, forms galls on black-currant shoots, the familiar and very serious **big-bud.** Not a few plant-mites form **galls.**

HARVEST-MITES.—Some people, especially thin-skinned people, are made miserable in midsummer by the bites of harvest-mites, and many are unaware of the cause of the trouble. The whole matter is not so clear as one might wish, but in Britain there is at least one 'harvest-mite,' called *Microtrombidium autumnale*, the three-legged larva of which, very minute and of a bright red colour, fixes itself at the base of a hair on our skin, and bites in a manner strangely annoying for such an 'animalcule.' Why it is so irritating we do not know. The minute larvae get on to man's skin from the herbage, and a useful precaution for susceptible people to adopt is to rub some flowers of sulphur under the stockings. A little oil of citronella on the same place is strongly recommended, as it seems to be very obnoxious to the larvae. When the bite begins to be felt a drop of ammonia is very effective, and all rubbing of the part is to be avoided. Gilbert White writes in his *Natural History of Selborne*: 'There is an insect with us, especially on chalky districts, which is very troublesome and teasing all the latter end of summer, getting into people's skins, especially those of women and children, and raising tumours which itch intolerably. This animal (which we call a harvest-bug) is very minute, scarce discernible to the naked eye, of a bright scarlet colour.' The mature four-legged female mite is very handsome, about the size of a large pin's head, like red velvet. The larvae are sometimes seen on harvest-men (*Phalangidae*), on various insects, on the cat, and on chickens. But it is difficult to be quite sure, for the rearing of the larvae is baffling. It is probably safe to say that several European species attack man, but that in Britain we are sure only

of one. A Japanese species transmits the serious "kedani" or river fever.

MITES AND HIVE-BEES.—There are many different kinds of mites, and their interrelations with hive-bees are diverse. Dr. John Rennie and Miss Elsie Harvey, whose names are associated with Mr. Bruce White's in the discovery of the mite that causes **Isle of Wight disease,** have put these interrelations in some order. (1) There is the disease-causing *Tarsonemus woodi,* Rennie, now called *Acarapis woodi,* living in the breathing-tubes or tracheal system. (2) There are mites that feed on honey, pollen, and the juices of dead bees. They are, of course, commonest in hives that are not kept clean. (3) There are predacious mites that prey upon those we have just mentioned (2), and perhaps on the mite causing Isle of Wight disease. (4) There is one which is often carried about by the hive-bee, but perhaps casually —*Tarsonemus apis,* Rennie. (5) There are two which use the hive-bee for transport, just as they also use humble-bees. It is likely that humble-bees are more profitable vehicles than hive-bees, for they go more among the herbage, whereas the hive-bees come mainly into contact with flowers and water. There are some mites that seem to be useful partners or commensals, but this is not known in connection with hive-bees. The study is an interesting one, for it illustrates the variety of linkages in **the web of life.**

MITES IN GRASSHOPPERS.—When it was shown by Rennie, White, and Harvey in their joint paper of 1921 that a mite (*Acarapis woodi*), parasitic in the tracheae of the hive-bee, was causally associated with the so-called ' Isle of Wight ' disease, the case was unique. It appears, however, that the occurrence of a mite in the tracheae of a grasshopper was noticed in 1914, though not published, by Mr. C. C. Hamilton, a student at the Kansas Agricultural College. Now we have in the *Annals of the Entomological Society of America* (1925, xviii. 35–44) an account of this mite, which is a frequent inmate of the tracheal system of two kinds of grasshoppers, *Hippiscus apiculatus,* Harris, and *Arphia carinata,* Scud. It is a Tarsonemid mite, named by H. E. Ewing *Locustaracus trachealis,* with some resemblance to the bee Tarsonemid *Acarapis woodi.* In both sexes there is a complete absence of the fourth pair of legs. Mites and eggs occur together in the principal tracheae and air-sacs, especially in the thoracic region and anterior abdomen. The infestation may be so severe that certain tracheae and air-sacs are quite blocked. There was some discoloration of surrounding tissue, probably due to the blocking and to feeding-punctures. For some unknown reason, only the adult female grasshoppers were found to be infected. It looks as if fully formed adult mites emerged from the eggs. This occurrence of another tracheal mite is very interesting. More cases will probably be found.

RED SPIDER.—This name is applied to injurious mites belonging to the genera *Tetranychus* and *Oligonychus*, which infest hop plants, fruit trees, violet plants, and the like. The word 'spider,' of course a misnomer, refers to the fact that the mites cover the under-side of the leaves with silken webs. In some cases these are so abundant that the plant, e.g. a whin bush, looks as if it were thickly covered with spiders' webs. The primary use of the web seems to be to fasten the eggs to the leaf. The threads of silk come out at a nipple-like projection near the hind end of the mite, and their adjustment is guided by the legs. Warm dry weather favours the multiplication of the mites, which hatch from the eggs in about a week and are full-grown in another week. So there may be many successive generations in a short time, and as the food consists of the juices of the plant, much harm may be done. All sorts of applications of sulphur, especially liver of sulphur (i.e alkali sulphides), have been tried as counter-actives, besides paraffin emulsions and various washes, but the 'red spiders' are hardy and agile. They retire into cracks and crevices and wait for better times. The winter is spent in the adult state under stones, clods, and bark. It may be noted also that the newly hatched mites have, as is usual, only three pairs of legs, and that the colour is greenish-yellow to start with.

BLEEDING TICKS.—There are leathery ticks, e.g. *Argas reflexus* and *Argas persicus*, which sometimes fasten themselves to the legs of sleeping poultry and draw blood, infecting the birds at the same time with a serious disease. It has been noticed by P. Remy that after a heavy meal these ticks eject blood when they are touched. The blood comes out at the apertures of what are called the coxal glands, and the theory is that the ejection is a means of relieving the uncomfortable repletion of the tick's alimentary canal after a heavy meal of chicken's blood. What is expelled from the tick's food-canal into the general cavity of the body is the watery part of the ingested blood, but in passing this out by the coxal glands some of the tick's own blood has to be sacrificed as well. It seems too clumsy to be quite true.

POISON OF DOG-TICK.—One of the many advantages of living in a country like Britain is that we are free from most of the poisonous pests which are common in more genial climates. Even our adder is now very much in the background, and our mosquitoes have lost their malaria germs. We were thinking of this the other day when we read Dr. Stewart M'Kay's account of how his pet Airedale suffered from a tick (*Ixodes holocyclus*) which became attached during a run-away excursion near Sydney. The female tick fixes its mouth-parts and injects poison. This acts as a local anaesthetic and also keeps the blood from clotting. But the poison is carried to the brain, and this

leads to irritation of the branches of the nerve going to the throat, lungs, and heart. Later on there is paralysis of the muscles of swallowing, and an irritation of the muscles of the stomach which causes vomiting. The heart action is seriously disturbed, there is a fall in blood-pressure, breathing breaks down badly, there is unsteadiness on the legs and then a collapse, paralysis of the hind-legs sets in, and then of the fore-limbs. The animal lies on its side quite unable to move. Coma supervenes and then death. And all from a drop of poison, the use of which to the attached tick may be that it obtains a prolonged supply of blood during the period when it is producing its two thousand eggs. Children may also be bitten with equally serious effects.

THE MINDS OF WATER-MITES.—In ponds and ditches among water-weeds one often finds minute mites which are sometimes very attractive. Not a few of them have singularly beautiful colours and look like living jewels. Many of them belie their relationship with the multitudinous mites found in the great cavern of an old cheese, for they are extraordinarily active. They go a-hunting all day and all night, swimming deftly and with apparent zest. We have kept some which seem to us to be literally indefatigable, bustling about at all hours. For their size they are mightier than whales. But what about their minds?

It does not seem possible to do justice to higher animals like dogs, horses, elephants, and monkeys without crediting them with a capacity for intelligent behaviour when this is urgently required. No doubt they have some instinctive, some reflex, some habituated behaviour; but at times they are genuinely intelligent. That is to say, they are able to profit by experience in a knowing kind of way; they put two and two together and show a spice of judgment, or some understanding of the situation; they are **educable.** If we could see into their minds we should probably discover that they are beginning to have a sort of picture-logic, what is called ' perceptual inference.'

But the difficulty is to decide whether intelligence may also be inferred in the case of very much simpler animals, and here the only safe guide is experiment. Hence the value of the recent experiments that Professor W. E. Agar, of Melbourne University, has made with water-mites or *Hydrachnids*.

A Y-shaped trough was made with unequal arms, and placed horizontally in a tank so that the floor of the trough was just below the surface of the water. There was enough water in the trough to allow the mite to get along, half-swimming, half-crawling. When it reached the forking end of the stem of the Y, it had to choose between the long left passage, closed at the far end with a little pane of clear glass, and the short right passage, which allowed escape into

the deep water. Various helps towards discrimination between right and left were given; thus the exit passage was sometimes black and all the rest white, or the right side of the stem and the whole of the exit was sometimes lined with chamois leather, the rest with smooth porcelain. Or there might be an electric shock in the left passage!

Twenty-one experiments were made, involving nearly five thousand trials in all, but there was no tendency for the number of errors to decrease as the experiment proceeded. The Australian freshwater crayfish, on the other hand, learned very rapidly to make the right choice.

A graduated glass tube, about a sixth of an inch in diameter, with turned-up ends, was filled with water and immersed in a trough which had a Bunsen burner near one end and a flow of cold water at the other. The mite could swim freely along the tube if it kept to a nearly straight line, and the point of the experiment was to discover whether it would direct its movements so as to avoid the very injurious warmth. The answer was an emphatic affirmative: the mites tend to avoid the injuriously hot parts of the graduated tube.

It was also noticed that the behaviour was more variable in the warmer sections of the tube than in the cool sections. The length of the run was shorter, and reversals of direction were more frequent, including those which delayed its escape from the dangerous conditions. In short, there was some excitement. Only in one experiment was the hottest region ever entered. The mites showed some sense!

Picture an energetic mite that has found itself in water of abnormal temperature, either higher or lower than usual, what does it do? It *experiments* by frequently reversing the direction of its swimming, and hundreds of observations show that the variability of behaviour increases in proportion to the degree of abnormality. It pursues what is called 'the trial-and-error method,' stopping a certain line of activity when it yields no relief, but continuing it if relief begins to be afforded. This is a step towards intelligence, which probably evolved many times independently in different groups of animals. A man would argue, 'The water is becoming warmer; I must swim away from the geyser'; or, 'The water is becoming colder; I must steer away from the icebergs'; and that would be intelligent reasoning, if not reason. The water-mite is just at the first step of the long staircase of behaviour which has led up to man's reasonable ways. But first steps are very interesting.

Professor Agar lays emphasis on the fact that the water-mites (mostly species of *Eylais*), that he worked with, catch their prey (minute crustaceans called water-fleas or *Daphnia*) by chance collisions as they swim about. They do not search for their prey by means of sense-organs, and animals with such a mode of life can have little need of, or scope for, intelligence.

We venture to say that it is only among the highest animals, such as dogs, horses, elephants, monkeys, and apes, that we find any instances of creatures that are cleverer than they need to be. Only in man is intelligence valued for its own sake.

Animals behave in many different ways, but there is a divergence between simply obeying their inborn predispositions (such as reflexes and instincts) and pursuing what may be called a tentative or experimental trial-and-error method. In the second kind of behaviour the animal plays its cards; it feels its way; if one reaction gives no relief or satisfaction, it tries another; it profits by experience, for it enregisters its failures and successes. Much of this tentative behaviour, like that of the mites in the graduated tube, is below the level of intelligence; but it points in that direction.

PENTASTOMIDS.—Without much satisfaction we may include here some strange animals called *Pentastomids* or *Linguatulids*, found in the nasal, frontal, and some other cavities in dog, wolf, monkeys, pythons, crocodiles, and other hosts. They are worm-like, externally ringed, with two pairs of movable hooks beside the mouth. The final larval forms have two pairs of short legs. In some cases two hosts are required for the completion of the life-history, e.g. rabbit and dog. One of the best known is *Linguatula taenioides* of the dog's nose.

PYCNOGONIDS.—Also very difficult to place are the so-called **sea-spiders** or *Pycnogons*, all marine. There are usually seven pairs of limbs, rarely eight, but the first three pairs are apt to be reduced. There is a suctorial proboscis, and some of the slow-going creatures suck the juices of sea-anemones and zoöphytes. The males carry the laid eggs till the young are hatched, and the young are sometimes seen clambering about his body. Common on the seashore is *Pycnogonum littorale*, while the large orange-red *Nymphons* from the Deep Sea are good instances of long-legged creatures that stalk about, as if on stilts, over the treacherous ooze.

BEAR ANIMALCULES.—Another puzzling order is that of the Bear Animalcules, Water Bears, Sloth Animalcules, or **Tardigrades**, very minute creatures with four pairs of unjointed clawed legs which are like little stumps. The mouth-parts are a little like those of some mites, but the position of the bear animalcules in relation to other animals remains undecided.

Bear animalcules are among the commonest of animals, yet few people ever see them. One reason for this is their minuteness, for, although they are many-celled animals with four pairs of legs, a brain, a food-canal, and so forth, they rarely exceed a millimetre (that is, one twenty-fifth of an inch) in length, and many are only a third of that. A second reason for their neglect is that they live a hidden life, being what is called **cryptozoic** (cf. p. 365). They frequent

such places as the choked roof-gutters of houses, holes in decaying trees, a patch of damp moss, or a stagnant ditch; and as they move very slowly they are among the most unobtrusive of living creatures. They have taken refuge in the crevices of the world and keep themselves to themselves. It is doubtful whether they have any near relations, unless, perhaps, mites.

Small as they are, bear animalcules can be usually recognized at a glance by those who hunt with the microscope. A side view, showing four of the stump-like clawed legs, suggests a microscopic hippopotamus with its head depressed. As the late Sir Arthur Shipley put it, ' some species look like dear little sucking-pigs in plate armour.' In many cases the minute body bears bristles, often long, usually countable. Some bear animalcules are transparent, others have reddish or brownish pigment; the surface plates are often finely sculptured or dotted; but the total appearance is quaint rather than elegant.

In the popular name 'bear animalcule' and in the technical name *Tardigrade* (also applied to the sloths) there is a reference to the very deliberate sluggish movements. The record is about one two-hundred-and-fiftieth of an inch per second, so that about four minutes would be required to traverse an inch. But that would be quick going, illustrated, for instance, when the marine *Batillipes* descends rapidly into the sand in stormy weather. A few climb rather neatly among water-plants or moss, gripping with their claws; but most are very awkward. Their dispersal from place to place is due to water-currents, wind, or attachment to larger animals such as aquatic insects.

Bear animalcules are for the most part vegetarian, sucking the juice of plant-cells, which they perforate by means of two stilets protrusible from the mouth. Occasionally they eat minute animals like wheel animalcules (*Rotifers*). For long periods they can keep alive without eating anything at all, and in any case they are not creatures with clamorous demands. They do not seem to have many enemies, but hungry amoebae and their enshelled relatives, the *Difflugias*, sometimes engulf the eggs or individuals that have recently moulted. Some threadworms or *Nematodes* are also to be reckoned with, and minute moulds may sometimes invade the body.

The sexes are separate, but in some genera (*Echiniscus* and *Milnesium*) the males have never been seen. The eggs are fertilized in the ovary, and then liberated singly or in groups. Sometimes they are left to develop inside the moulted cuticle. In many cases the egg-shell is ornamented with puzzling roughnesses of very definite shape. After developing for a longer or shorter time (from a month to four days) the eggs hatch, the young bear animalcule boring its way through the shell. It is a miniature of the adult that emerges; in other words, the development is direct, without any larval stage.

As the bear animalcules often live in surroundings that are apt to dry up, it is not surprising to find that many of them can adapt themselves to this contingency. They are, indeed, famous for their power of becoming like dry dust, without losing the power of renewed activity if water is supplied in time. If we had a clearer understanding of the dried-up Tardigrade and its retention of vitality, we should have advanced appreciably in our understanding of the ordinary activity of life.

When a patch of moss dries up, the bear animalcules soon begin to change their shape, drawing in their head, legs, and tail end, and often curving towards the under-side of their minute body. They assume what is called the ' barrel ' shape. It has been proved experimentally that this is not directly due to the absence of water from the capillary spaces between the moss leaves, but rather to the diminution or absence of the oxygen which is normally contained in the water-films. But as the bear animalcules become drier and drier they sink into a strange state of **suspended animation,** which may last for months or even years. They show no sign of life and yet they are not dead, as is proved when they become lively again.

The extraordinary feature is the apparent indifference of the desiccated Tardigrades to outside influences, such as cold down to −27° Centigrade, heat up to 100° Centigrade, reagents like corrosive sublimate, and radiations such as radium rays and ultra-violet light. They lie low and do not seem to mind. There may be revival after about six years of ' dried-upness ' (or **desiccation**), but not after eight years. Of course the drying-up is not absolute; there remains, for instance, the water that is bound up with many of the complex molecules of the living body.

Some of the limits are interesting. Thus the little creatures cannot be dried and wetted indefinitely; ten times is the maximum. The marine *Batillipes* that is never dry in its natural environment dies in six minutes when taken out of water, whereas *Echiniscoides* from between tide-marks can survive ten days' drought. Little is certain in regard to those forms that live in permanent freshwater basins.

In some types the revitalizing comes about very rapidly; in others it takes hours before the barrel-shaped state gives place to the normal form. Not to be confused with the ordinary dried-up state is the **encystation** which is induced by starvation and other untoward conditions. In this case the animal retracts itself within its cuticle, as if it were going to moult; but it remains inside the old husk, which tends to break up, and makes a new one, the so-called **cyst,** within which a third may also be formed.

The best book on bear animalcules is by Ernst Marcus, to which we acknowledge our indebtedness for some new facts. Interesting

creatures they are, for, besides their return from the gates of death, they are in many ways rather striking, except in size. Thus it is almost startling to find a highly developed and relatively large nervous system, not very different in type from that of mites. Most of them have two simple eyes, usually black or red. They probably enjoy a longish life, for they are sparing in their expenditure of energy; but they are known to grow old and to die a natural death if they are left to themselves.

THE KING-CRAB.—One of the sights of a well-equipped aquarium, like the Aladdin's cave in the London 'Zoo,' is the king-crab. We do not think it is an irrational impulse that prompts us to take off our hat when we stand before his tank. For it is not merely that he is fearfully and wonderfully made, he is a 'living fossil' with an impressively long pedigree. Perhaps we should have begun by saying that he is not a crab, and has nothing to do with crabs. For he is the only living representative of an ancient race that was already very old three hundred million years ago. The present-day genus, called *Limulus*, goes back to Triassic Ages, and there are well-preserved king-crab fossils in the famous Jurassic lithographic stones of Bavaria that yielded the precious remains of the first known bird, *Archaeopteryx*. The progenitors of this very creature *Limulus* that we see in the tank, perhaps the quaintest marine animal living to-day, were pursuing the uneven tenor of their way long before birds had even begun to fly. But when we think not of *Limulus* itself, but of its extinct relatives, members of the sadly dwindled class of *Xiphosura*, we have to force our halting thoughts back and back through many hundreds of millions of years. For *Belinurus* and *Prestwichia* are fossil Xiphosurans from the Carboniferous, *Neolimulus* and *Hemiaspis* from the Silurian; and further back still the lineage goes. Few anthropologists would be inclined to grant *Homo* an antiquity of more than a million years, and many grudge him half that number. What newcomers we feel ourselves to be as we look at *Limulus* on the New Jersey shore! As a genus he is many millions of years old, and he belongs to a race whose antiquity is even more unthinkable. What tenacity of life there is in some of these archaic types!

Quaintest of marine animals we have called the king-crab, but the shape of the body is very pleasing. Over the head and thorax there is a vaulted shield, shaped like a saddler's knife; and this is continued, on the other side of a flexible transverse joint, into another shield somewhat hexagonal in outline. To the indented posterior side of the hexagon there is hinged a long, sharp spine, a 'tail-spear,' to which the technical word *Xiphosura* (*xiphos*, a sword; *oura*, a tail) refers. It is an ugly thing to put one's foot on when one is wading at low tide. Looked at from above the two shields suggest the outline of a

horse's hoof, hence the common American name of 'horsefoot' or 'horse-shoe crab.' We wish we could get rid of the 'crab' part of the name, but it is impossible. When is a fish not a fish? When it is a cuttlefish or a shellfish or a blackfish or a silverfish or a starfish! When is a crab not a crab? When it is a *Limulus*.

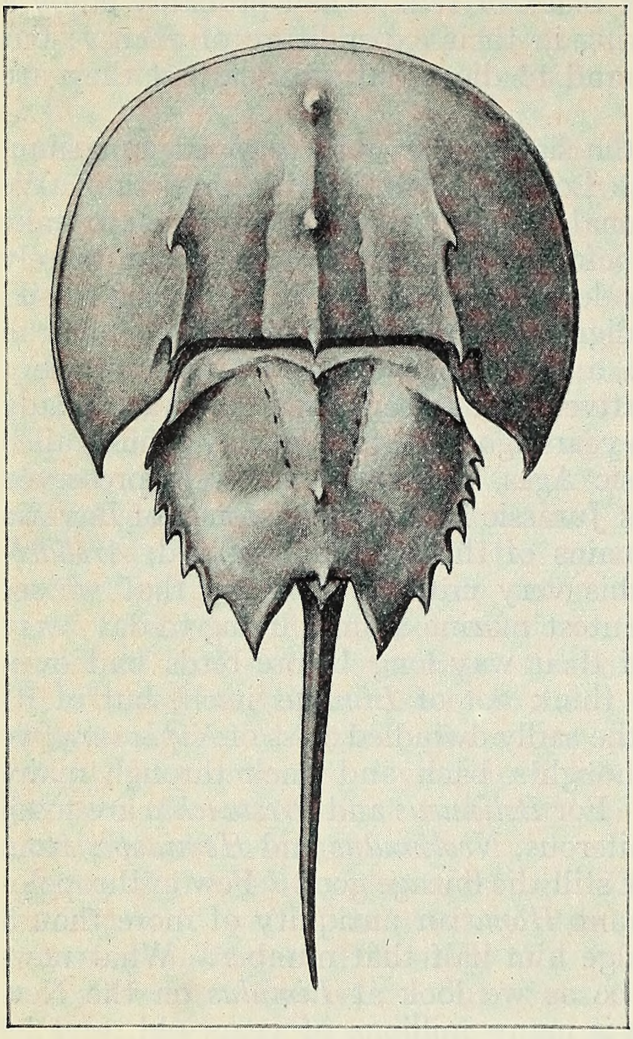


Fig. 149. King-crab (*Limulus*), Dorsal View

The king-crab has been described as having 'a self-respecting, well-groomed appearance'; it never has anything growing on it, perhaps because it is a burrower. Its shell varies from sage-green to black in colour. Some of the big ones are extraordinarily handsome, as one expects aristocrats to be. But we can hardly say that they move with dignity, for their ways are peculiar. When burrowing in the soft sand they gouge forwards and downwards with the saddler's knife, bend the body upwards at the hinge between the two shields, push forward with their spear, and then straighten out again. Meanwhile some of the anterior legs on the under-surface of the front shield are vigorously scratching the sand out sideways. At night, when the king-crabs often leave the sand and go a-roving in the water, they swim in a series of short hops, propelling themselves by means of plate-like posterior limbs, which also carry the gills or gill-books. In the swimming-jerks the body forms an angle of forty-five degrees with the ground, and 'between each two short flights the animal balances itself for a moment on the tip of its tail.' We have quoted the last sentence so that it may be more readily believed, for we cannot remember any other animal that balances itself in a manner so original. Perhaps the sea-urchin that hobbles along a flat, firm surface on the tips of its teeth comes a good

second. The king-crab also uses its tail to right itself when it tumbles on its back, a gymnastic display very interesting to watch.

When the creature is on its back we may have time to see that it has seven pairs of limbs under the anterior horseshoe, and we may possibly see that it has six pairs under the posterior hexagon. In this connection it is interesting to notice the entire absence of feelers or antennae, an absence which is perhaps enough in itself to show that the king-crab is nearer to scorpions and other Arachnids than to crabs and other Crustaceans. But pedigrees are vexatious subjects, and we had better leave that of the king-crab alone. Perhaps the clearest fact is that its race shows relationships with the Palaeozoic sea-scorpions or *Eurypterids*, which poetical quarrymen have sometimes called 'fossil seraphim.'

The five last pairs of limbs carry unique breathing organs, which are called 'gill-books.' Each is like a book, fastened to the limb by its back, and consisting of 150–200 hollow leaves. Inside the leaves the blood flows, while the flat surfaces of the leaves are bathed by the oxygen-containing water. Inside the cavity of the body, which is much smaller than one would expect, there are the usual essential organs, such as brain, heart, and food-canal.

The king-crab feeds chiefly on sea-worms which it catches by burrowing in the sand, and crunches or 'cards' into its mouth by rapid movements of the bases of the walking legs. Sometimes for a change it crunches small bivalves.

The males are smaller than the females, but of similar appearance. The spawning occurs in the summer months, and the pearly eggs, externally fertilized, are deposited by the American species in a number of shallow nests in the sand, while in the Moluccan species they are carried about attached to the mother's swimming limbs. Active little larvae eventually burst out of the egg-envelopes; they swim vigorously and burrow into the sand, differing markedly from their parents in the absence of the tail-spine. They feed, grow, and moult, the moulting occurring about half a dozen times in the course of the first year, and after that less frequently till full size is attained. A split along the under-surface of the anterior rim of the horseshoe allows the moulting king-crab to creep out ventrally; and some quaint people assert that it gets its new suit by creeping out of its own mouth.

One of the interesting facts about king-crabs is their geographical distribution, for they occur in two widely separated regions, one species on the coast of Maine and others in the Far East; for instance, in the shore waters of the Philippines, Moluccas, Borneo, and Japan. King-crabs are not of much use except to testify to the glory of the Creator, for, although they are given as fattening food to pigs and poultry, they infect the flesh with a distinctly archaic flavour which depresses the market value.

CHAPTER XV

MOLLUSCS

Molluscs contrasted with Arthropods—Survey of Molluscs—General characters of Molluscs—In illustration of Bivalves—The freshwater Mussel—Oysters—In illustration of Snails and Slugs—Survey of Gasteropods—The Wintering Snail—Does a shell echo the murmur of the sea?—Cuttlefishes and Nautili—Survey of Cephalopods—The Pearly Nautilus—The Argonaut's cradle—Conchology.

MOLLUSCS CONTRASTED WITH ARTHROPODS.—There is no doubt that Molluscs, that is to say animals like cockles and mussels, snails and slugs, cuttlefishes and *Nautili*, are on a line very different from that of the jointed-footed animals or Arthropods, such as crabs, insects, and spiders. What are the chief points in the contrast? The Arthropod has a segmented body with numerous jointed appendages; the Mollusc has an unsegmented body without any appendages. The Arthropod shell or cuticle has an organic foundation of **chitin,** to which in Crustaceans some calcium carbonate is added; the Mollusc shell or cuticle has an organic foundation of **conchin,** to which much calcium carbonate is usually added. Moreover, as the Mollusc grows it usually adds to the free margin of its shell, so that there is not that recurrence of moults which is so characteristic of Arthropods. While Arthropods tend to be very active and have usually much striped muscle, quickly contracting, the Molluscs tend to be slow-going and have much unstriped muscle, slowly contracting. Very characteristic of Molluscs is a muscular development of the ventral surface, called the **foot**; but in spite of its name it is not in any way of the nature of an appendage or limb. In Arthropods there is, as we have noticed, a typical form of nervous system, namely a dorsal brain, a ventral chain of ganglia, and a ring round the gullet connecting the two. But in Molluscs there is an entirely different type of nervous system, to be described later. Finally, the larval forms of Molluscs, when there are any, are not at all like any of the Arthropod larvae.

SURVEY OF MOLLUSCS.—There are three great classes in the assemblage or phylum; namely (A) the snails and slugs, in water and on land, the **Gasteropods**; (B) the bivalves, such as cockles and mussels, oysters and clams, some in fresh water, but mostly in the sea, the **Lamellibranchs**; and (C) the cuttlefishes and the pearly nautilus, the **Cephalopods.**

To these three great classes may be added: (A^1) the **Solenogasters,** a small class of primitive and rather worm-like forms, e.g. *Neomenia*; and (A^2) the **Scaphopods,** a small class of peculiar forms whose shells resemble miniature elephant-tusks, e.g. *Dentalium*. Distantly related to the nautilus, which is the last of its race, there is a great series of beautiful fossil forms called **Ammonites.**

GENERAL CHARACTERS OF MOLLUSCS.—(i) As has been mentioned, Molluscs are unsegmented and without appendages. (ii) Except in the majority of Gasteropods, the body is bilaterally symmetrical. That is to say, there is one dorso-ventral median cut that would divide a mussel, or a clam, or a cuttlefish, or a nautilus, into two mirroring halves. But the body of almost all the Gasteropods is twisted to the right-hand side forwards, so that the food-canal ends not far from the mouth, where it begins. Moreover, the internal organs tend to become ruptured out dorsally in a hump, ' the visceral hump,' and this becomes twisted in a spiral to which the coiled shell corresponds. Thus there is no possibility of halving a typical snail or its shell. That is to say, it cannot be cut into two mirroring halves, like the shell of a pearly nautilus.

(iii) Very characteristic is the '**foot,**' a muscular development of the ventral surface. It forms the flat sole on which a snail creeps along, the ploughshare-like organ by means of which a freshwater mussel draws itself slowly through the mud, the bent little-finger-like protrusion with which the cockle can take short jumps on the sand; and it is divided up to form the sucker-bearing arms of the cuttlefishes. It is usually a locomotor structure, but it occurs in diverse forms according to the animal's habits. In the sedentary bivalves like oysters, it is much reduced. Its typical hatchet form in bivalves has given origin to the technical name **Pelecypod** (*pelecys*, a hatchet; *pod*, a foot), which is a synonym of *Lamellibranch.*

(iv) A dorsal fold of skin, called the **mantle,** is thrown forwards towards the head in snails and cuttlefishes, and encloses a respiratory cavity. In bivalves, on the other hand, the folds are lateral, forming a flap on each side of the body, recalling the right and left flaps of a jacket. This mantle is characteristic, but it is occasionally suppressed.

(v) Every embryo mollusc has a microscopic dorsal shell-sac enclosing a shell, probably an ancestral relic. This comes to nothing. In most molluscs what becomes the adult shell is a secretion of the mantle, and thus it is one piece in Gasteropods and Cephalopods, but bivalved in Pelecypods. In many cases, like black slug and *Octopus*, it has been entirely suppressed. The shell consists of calcium carbonate and conchin, and is added to as the mollusc grows.

(vi) In molluscs there are three chief pairs of interconnected nerve-centres or **ganglia**—the cerebrals, which control the head; the

pedals, which control the foot; and the pleurals, which often send off a nerve-loop to the digestive and other organs, bearing a pair of visceral centres. This is a difficult matter for a book of this kind, so it is perhaps better to emphasize the fact that molluscs show *very little hint of the ventral nerve-cord* which is characteristic of ringed worms and jointed-footed animals. The greatest concentration of nerve-centres among backboneless animals is seen in snails and cuttlefishes.

(vii) In bivalves the head region is very poorly developed, and the mouth is a '**soft-mouth,**' with delicate ciliated flaps or palps, entirely suited for the in-wafting of microscopic organisms and particles. But in the other molluscs, the snails and cuttles, which have the head well developed, the mouth contains a very characteristic rasping ribbon or **radula.** It is a little like a flexible file, a ribbon of chitin bearing numerous minute teeth, which serve to cut the food or to bore a hole in a shell, and so forth. The flexible file is pulled backwards and forwards by muscles over a firm cushion on the floor of the mouth, and the whole apparatus is called the **odontophore.** It is a good exercise in manipulation to take out the radula (often called the **snail's palate**) from a dead specimen. It may be recognized by its grittiness when touched with the dissecting needles, and it often has a faint yellowish colour. It is not to be confused with the more substantial and quite simple **jaw-plate** on the roof of the mouth, which helps to grip during the rasping or filing operations. When the radula, placed in a little water and covered with a cover-slip, is looked at through the microscope, the rows of teeth will be seen; they are quite unmistakable. If the radulae of different kinds of Gasteropods are compared, their differences will be noticed at once, for each kind has its own type of file. This is a beautiful instance of **specificity,** i.e. each species is in detail itself and no other.

Cuttlefishes have a pair of parrot-beak-like jaw-plates, which are used in tearing the booty, such as crabs; but they have also a strong radula. One of the striking Gasteropod radulae is that of the limpet, which can be easily pulled out of a dead specimen. It is twice as long as the whole animal.

(viii) Most molluscs breathe by means of **gills.** Those of bivalves form large ciliated plates which assist in wafting food-particles into the mouth. Those of Gasteropods and Cephalopods are more plume-like. At the base of the gills there is usually a water-testing smelling organ (called the **osphradium**). Terrestrial snails and slugs breathe dry air, and the blood is spread out on the wall of the mantle-cavity, which is often called a lung or a **pulmonary chamber.**

(ix) Out of the egg of a land-snail, or of a cuttlefish, there comes a miniature of the adult. But in most Gasteropods and in Bivalves

there are two common larval stages: (*a*) a transparent microscopic top, like the larva of many sea-worms, called the **trochosphere,** and (*b*) a more characteristic **veliger,** with a special swimming structure, called the *velum*. Even a very sedentary mollusc, such as the oyster, has its free-swimming larvae, which undergo a marked change before they begin to show the characters of the adults. The general fact is that all cuttlefishes and bivalves, and most of the aquatic snails and slugs, have an **indirect development.**

In Illustration of Bivalves

The members of this class are bilaterally symmetrical, just like ourselves. On each side, right and left, there is a mantle-flap and a shell-valve. The foot is usually like a ploughshare. The head region has remained poorly developed, and there is a noteworthy absence of radula, jaw-plate, and tentacles. In most cases the gills form large basketwork-like plates, formed of ciliated gill-filaments bound together, hence the name *Lamellibranch* (*lamella*, plate; *branchia*, gills). There are usually three pairs of ganglia or nerve-centres: cerebro-pleurals above the mouth, pedals in the foot, and viscerals at the posterior end of the body, all connected by nerve-strands. The heart consists of a driving chamber or ventricle, and two receiving chambers or auricles; it is surrounded by a space called the *pericardium* (*peri*, around; *cardia*, the heart), which lies just below the ligament or hinge between the two shell-valves, and communicates with the exterior by means of two kidneys. Most bivalves are either males or females; a few are hermaphrodite, i.e. producing both egg-cells and sperm-cells. The typical development includes trochosphere and veliger larvae. Most bivalves feed on microscopic particles or organisms; most are rather sluggish. They occur in fresh water as well as in the sea; and they occur in the sea from the shallow shore waters to the great abysses.

THE FRESHWATER MUSSEL.—One man we have known who was genuinely enthusiastic over freshwater mussels, and he was a pearl-fisher and a rough diamond. He used to go about with an instrument like a magnified crochet needle, with which he yanked the mussels out of the mud, and he carried on his back what looked like a prototype of a telescope. It had at one end a pane of glass about a foot in diameter, and he looked through the other end in search of mussels. It was intended to defeat the ripples on the surface of the water, and might be called a hydroscope. The pearl-fisher waxed eloquent over the ' beauties ' he collected, but he couldn't or would'nt tell us anything about their Natural History. Even concerning their geographical distribution he was studiously vague. The first fifty

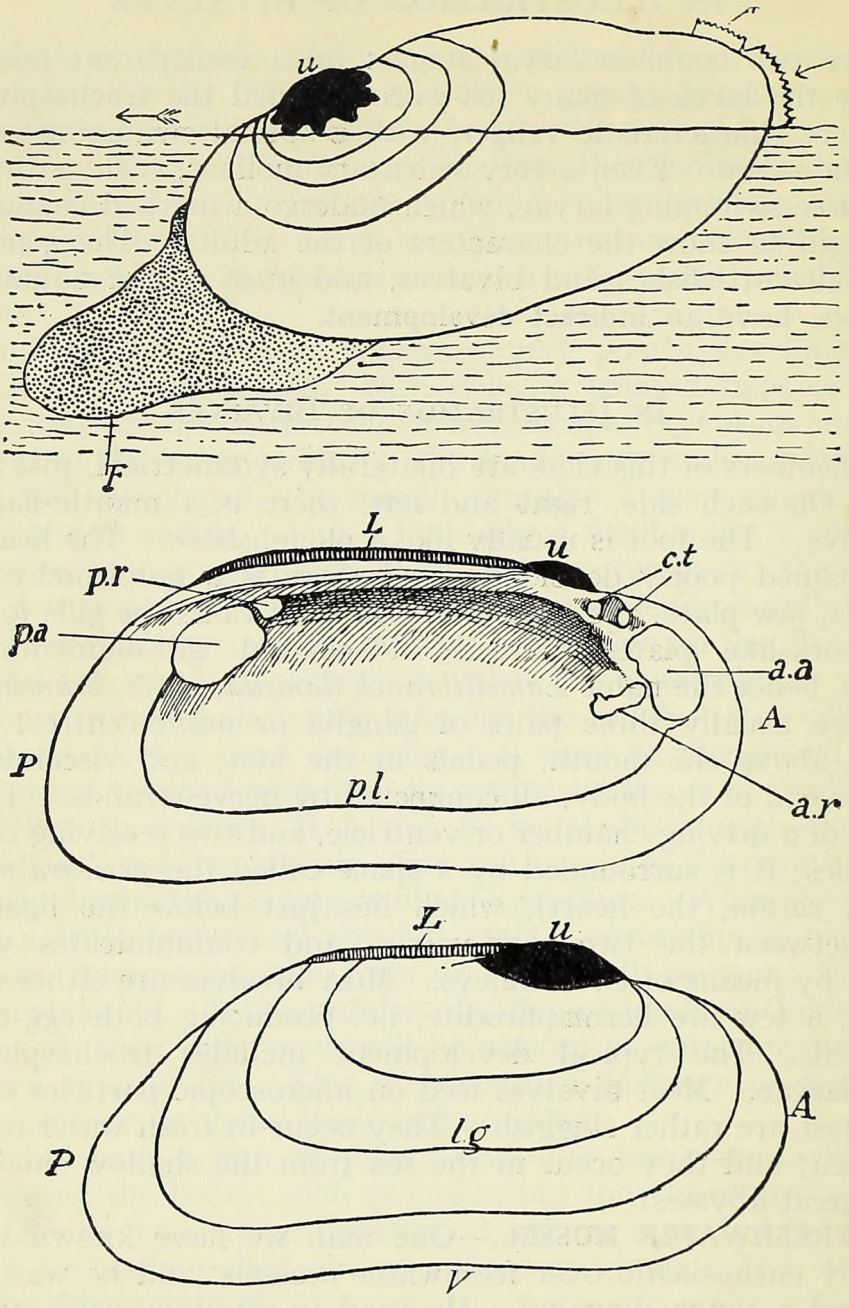


FIG. 150. THE FRESHWATER MUSSEL (*Unio*)

The uppermost figure represents the bivalve in motion in the mud, with protruded foot (F); note inhalant and exhalant apertures. The middle figure shows the inside of the shell (left valve). The lower figure shows the outside (right valve). *u*, umbo; L, ligament; *ct*, lateral teeth; *aa*, anterior adductor muscle-mark; *ar*, mark of protractor muscle of foot; *pl*, pallial line; *pa*, mark of posterior adductor muscle; *pr*, mark of posterior retractor muscle of foot; *lg*, line of growth; A, anterior (the blunter end); P, posterior; V, ventral.

mussels we bought from him on the riverside, for our students' use in the laboratory; but in his politeness he brought them to college 'gutted,' so that they were not of much avail.

Freshwater mussels are very reserved animals, and do not show off their habits; but they are interesting in many ways. The species that has long been fished in Scotland is technically called *Unio margaritifer*; it attains a length of five inches. A smaller one, whose valves used to be in request for holding water-colours, is called *Unio pictorum*. Both are at once distinguishable from the swan mussel (*Anodonta cygnea*) by having thick shells and strong teeth at the hinge.

The dark-coloured shell, with its oldest part often much corroded by unicellular Algae, shows 'lines of growth'; the faintly zoned intervals between the more prominent ridges probably represent a year's increase. The mussel may live for twelve years, a reputable age for a creature without a head—for this is one of its marked defects. The hinge-line is dorsal, and beneath it lies the heart; the opposite free and growing margin is ventral; and between the valves, when they gape, the muscular 'foot' protrudes. The sharper of the two ends is posterior, the blunter end is anterior, where the head should be, but is not. Such is the external topography of *Unio*.

A tortoise is in a hurry compared with the freshwater mussel, which must be one of the most easy-going animals in the world—outside of parasites. Half-buried in the mud, it protrudes its foot and then draws it back again, ploughing its way with extreme leisureliness. Oftenest, however, it does not move at all, but spends the tedious time in one long meal. By means of the myriads of cilia on the large gills, on the lips, and on the internal surface of the shell-making skin-flap or mantle, it wafts microscopical organisms and particles into its mouth. The usual time for exercise seems to be soon after sunset.

The spawning season is in early summer, in May or June, when the mussels seek the shallower, warmer water. The sexes are indistinguishable, and there is nothing that can be called coupling. All that one can say is that sperms from the male are wafted into the female and fertilize the eggs, which pass in a rather complicated way into the outer gill-plates. For several days the production of eggs continues, and there must be many thousands of them. But they are not liberated; the development goes on in the cradle already indicated. Latter points out that a typical molluscan larva, called a *veliger* (p. 385), is formed inside the transparent egg-shell, but, instead of being liberated as in marine relatives, it remains unhatched. Nevertheless for some hours it revolves inside the egg-shell, a quaint reminiscence of the marine origin of the freshwater mussel, probably many

millions of years ago. Such is the recapitulation of **phylogeny** (race-evolution) by **ontogeny** (individual development). What a memory life has!

It is characteristic of freshwater animals that they suppress the larval stages which are seen in their marine relatives. Thus the freshwater crayfish telescopes its larval stages and is hatched out as an almost exact miniature of the adult—a striking contrast to what is

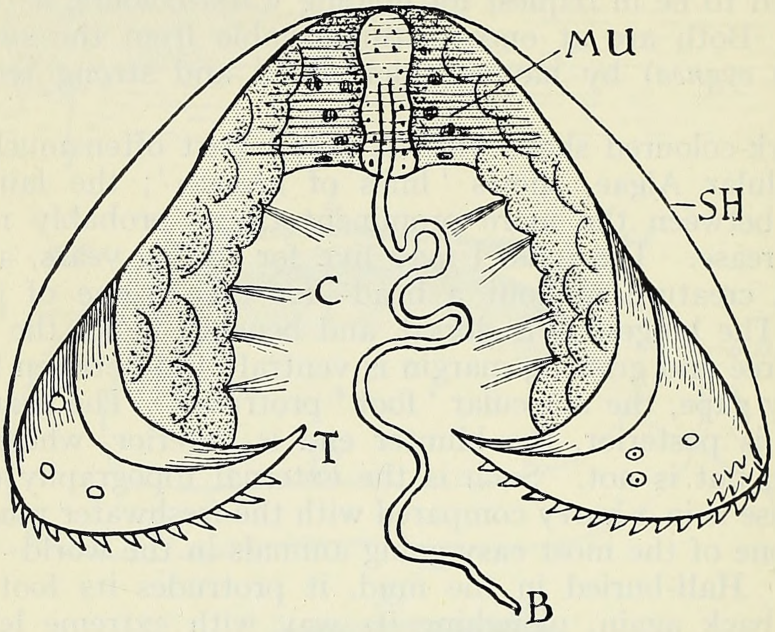


Fig. 151. Glochidium Larva of Fresh-water Mussel

SH, valve of the shell; MU, muscle-fibres working the shell; T, tooth on shell-margin; B, byssus, effecting fixation; C, tuft of sensitive cells. Size of larva about that of a very small pin's head.

true of a lobster or a common crab. The main reason for this suppression of larvae is to be found in the risks of being washed away. Yet there are, as every one knows, numerous insect larvae in fresh water; and the mussel is another exception. The explanation in these cases is that the larvae have some special gripping organs which save them from being washed down to the sea. This is remarkable in the minute mussel larvae, which are called **glochidia.** Theirs is an extraordinary story.

By October there has been formed inside the egg-shell a minute mussel, with a toothed beak at the tip of each triangular valve, and with a sticky thread called **byssus** which projects after hatching and glues the larva to the gill-cradle. Hatching occurs, but liberation is still far off. It is not till February or March that the glochidia, much smaller than the head of an ordinary pin, are expelled in tangled wisps; and this does not happen unless there is a stickleback or some other fish

in the vicinity. The entangled larvae may sink to the bottom or on to water-weed, but if a fish is near they clap their valves vigorously and become moored by the byssus to the skin. When the toothed beaks actually touch a fin or a gill they take firm grip, and the irritated tissue of the fish rises round them. In fact the glochidium is entirely covered up, and is carried about as a parasite for three months. It absorbs food from its host and undergoes a great change or **metamorphosis,** acquiring, for instance, two new valves underneath the original ones. Eventually the young mussel drops off into the mud, perhaps miles from the place where the glochidium took grip. Only certain fishes, such as sticklebacks and minnows, can serve as hosts; and without this strange chapter the life-history cannot complete itself. This is a striking instance of the way in which two animals very far apart anatomically may become closely linked together, and the interrelation becomes still more striking in the case of the continental fish called the bitterling (*Rhodeus amarus*), which lays its eggs, by means of a long **ovipositor,** in the interior of the freshwater mussel. Indeed, nothing lives or dies to itself.

It is believed that the fame of Scottish pearls was one of the inducements that brought Julius Caesar to Britain, and ' thay indeed schawe a schyneng brichtness, notwithstanding mair obscuir than thay quhilkes ar brocht in frome the Eist.' They are still to be found, but careless fishing has greatly reduced the number of mussels in most of the Scottish rivers. In the years 1761–4 the Tay fishery is said to have yielded pearls to the value of £10,000; but these days are long since past. Though it remains uncertain, it is probable that the finest pearls of *Unio margaritifer* are formed around the larva of a tapeworm or a fluke, whose adult stage occurs in some aquatic bird. Among the mussel's enemies apart from man must be reckoned several birds, such as coot and heron, and two mammals—the otter and the water-vole. Crows sometimes lift them from the shallow water and let them fall from a height on the shingle, so that the thick shells are broken—a device probably suggested by accident and then utilized intelligently. If we put one leg of an imaginary pair of compasses on a freshwater mussel and describe a circle, how many other lives will be intersected—from the little *Micrococcus conchivorus* that corrodes the shell to the resourceful otter that enjoys the flesh, from the little black and white mite, *Atax bonzi*, that shelters on the gills to the stickleback that acts as host to the glochidium! Such is **the web of life.**

OYSTERS.—The beginning of the oyster is a fertilized egg-cell, and out of the egg-envelope there comes a free-swimming larva. There are many of them, moving rapidly in the water, but there is enormous ' infantile mortality.' Most of them are swallowed by one or other of

the many animals of the sea that live on very minute swimming or drifting organisms. Only a few of the many larval oysters get the length of settling down as ' spat ' and beginning a quiet humdrum life on the floor of shallow inshore waters. Even then there are many hungry enemies, such as starfishes, prowling about, and if an oyster survives to be big enough to be eaten by man, it is a very lucky oyster indeed !

When we look at an oyster we see a shell with a great deal of character. Thus there are many narrow **lines of growth** on the valves, strangely irregular often, indicating vicissitudes in the oyster's every-day life. But these smaller lines may be grouped in a few larger zones, each of which indicates the growth of a year. Thus, after some experience, we can tell how old our oyster is. The distinctness of the year's growth is due to the interruption of feeding (in North Europe) between the end of November and the middle of March. When the oyster is fasting there can be no additions to the shell, but what is already formed becomes variously weathered and corroded, so that there is a distinct boundary line where each new year's growth begins.

Periodicity of Growth. It is in the very nature of life to be rhythmic; that is to say, there are more or less regular alternations of activity and rest, wear and repair, spending and saving, building-up and pulling-down. When these alternations or see-saws are of long duration they usually correspond to the seasons of the year. Thus the lines of age indicate, in the majority of cases, the active growth of summer and the slowed or stopped growth of autumn. This **zoning** is familiar in the sawn stem of a tree, where the early summer wood is different in texture and colour from the late summer wood, so that the rings are easily counted. Similarly the periodicity of growth is indicated by the lines on the scale of a fish, the vertebrae of a fish, the rings inside the spine of a sea-urchin, the parallel lines on the scales of a tortoise, the concentric layers of a pearl or in the ear-stones of a haddock, and in a score of other cases. But the ' line upon line ' method of growth is nowhere seen more clearly than in the shells of molluscs.

The oyster has unequal **shell-valves.** The left is more saucer-like, convex externally, and heavier in build; it is the lower one when the oyster has settled down. The right valve is flatter and lighter, uppermost in the fixed oyster. It is raised when the oyster ' gapes,' and being lighter it is easier to lift than the other one would have been. The straighter margin is posterior; the more bulging is anterior, that is, at the mouth end.

When we look at an opened oyster we at once see: (*a*) the fold of skin or mantle which lines the shell and makes the shell; (*b*) the gill-plates, two on each side, made up of many parallel filaments; (*c*) the central closing muscle which draws the two valves tightly together;

(*d*) a pad of conchin, called the **ligament,** squeezed in at the hinge between the two valves; (*e*) between the pad and the muscle a region including the heart, the liver, and the stomach. Below the mouth are two pairs of ciliated lips or **palps.** Conspicuous by its absence is the 'foot,' a strong muscular organ of locomotion in most bivalves, but undeveloped in the sluggish oyster.

THE OYSTER'S FEEDING AND BREEDING.—For many years it has been held that oysters feed on very minute living organisms, such as diatoms and infusorians. In other words, the general belief has been that oysters feed on the micro-plankton—the small creatures, whether plants or animals, that drift about or move in a leisurely way in the water. But this conclusion seems to have been a mistake, for the very careful investigations of Petersen and Jensen show that most of the oyster's food consists of minute detritus—the particles rubbed off from the wear and tear of seaweeds and sea-grass. The microscopic examination of the oyster's food-canal may show a few of the diatoms that live on the floor of the shallow water, but the contents consist mainly of minute fragments of what one might perhaps call organic sea-dust. A Danish biologist, R. Spärck, recently fed oysters with a greenish pulp made out of rotting sea-wrack (*Fucus*) and sea-grass (*Zostera*), and found that they used it abundantly. This is all the more interesting in that oysters are by no means given to taking every kind of food that is offered. Even the oyster chooses. Moreover, in North Europe it is the oyster's habit to fast from the end of November to the middle of March, and when the experimenter gave them seaweed and sea-grass pulp during these months they simply left it alone. They prefer to fast.

When an oyster is feeding actively, sweeping microscopic particles into its mouth by means of the cilia on its gills and mantle, it seems to reject nothing that is suitable. What is called the 'fattening' of oysters appears to be due to a consumption of diatoms, but the growth is due to detritus, the animate food never exceeding 10 per cent of the total. A grim instance of the struggle for existence is recorded, that in the water of the Conway oyster tanks the larvae were present in large numbers from July to September, and in the stomachs of the oysters from the tanks—an artificial environment—they sometimes reached the amazing amount of 96 per cent by bulk of the total contents of their parents' food-canal. Fortunately, some of them are able to survive this hazardous passage.

A curious feature of oysters and many other bivalves is the presence of a clear '**crystalling style**' in the food-canal. It is a translucent compact rod that rotates in the intestine, and is usually regarded as a nutritive reserve. When the mollusc is starving, as in midwinter, the crystalline style disappears; when suitable food is supplied the style is formed afresh. Its presence or absence depends not merely on the

degree of cold; there is something subtler. The style disappears when the water is too warm in summer, as well as when it is too cold in winter; it disappears when food is scarce at the feeding season. Whenever the ordinary routine is seriously disturbed, the style is lacking. As Spärck says, information in regard to the state of health of a stock of oysters can always be obtained by opening some of them and looking for the style. If it is present all is well; if it is absent there is something wrong, except in winter, when its absence is normal.

Another sign of adversity in oysters is the paralysis of the shell-closing muscle, which betrays itself, of course, in the *gaping* of the valves. This **paralysis** occurs in various degrees, and it may continue for a long time without being fatal. But a gaping shell is an opportunity for the starfish and the shore-crab, both of which are very destructive to oysters and can open them even when there is no gaping of the shell. It seems that various causes may bring on the paralysis, such as insufficient food or abnormal temperatures—either too high or too low. Apart from fishing, the death-rate of fixed oysters in the Limfjord is about 20 per cent per annum.

Oysters that are called ' white-sick ' are anything but sick; they are simply breeding-oysters with a large number of developing eggs. This stage is succeeded by ' blue sickness,' another absurd name, for it simply refers to the fact that the eggs have become larvae, which will soon be set free. It is very different, however, with ' green ' oysters, for the probability is that the green colour is due to intruding parasites or, it may be, symbionts. The condition occurs normally in the famous Marennes oysters and in those from some other localities on the coast of France, and it is of casual occurrence elsewhere, for instance in the Limfjord in 1921. The old view was that the green colour was due to an abundance of diatoms in the water; but, as we have seen, diatoms do not form an important part of the oyster's diet, and the creature does not take in what it does not want. Moreover, the green colour has been observed in other animals in the vicinity, as in the locomotor tube-feet of the common starfish. Thus Spärck is inclined to the provisional theory that ' green ' oysters are infected by some simple intracellular parasite or symbiont, like the ' green cells ' which occur inside some sea-anemones and corals. That the intruders are parasitic rather than symbiotic is suggested by the fact that green gills putrefy much more rapidly than those that are of the ordinary colour. But this is obviously a question that demands further investigation. In some cases 90 per cent of the oysters turn green.

The breeding of the oyster is not less interesting than its feeding. In the first place it may be noted that in some oysters the sexes are normally separate. Thus, though occasional hermaphrodites occur, there are normally separate males and females in the American oyster

(*Ostrea virginica*) and in the Portuguese oyster (*Ostrea angulata*). But in the common oyster (*Ostrea edulis*) and in some other species there is hermaphroditism—that is to say, the sexes are combined in one animal. This has been generally recognized for a long time, in spite of a good deal of controversy, for which Spärck has now shown that there was justification. Spärck's studies, in fact, seem to prove up to the hilt that the common oyster changes its sex. It is an *alternating hermaphrodite*—at one time a male, and at another time a female.

To begin with, the mature oyster is a male; later on it becomes an egg-producing female; by and by it becomes a male once more, and so the alternation continues, year after year. The production of eggs is promoted by increased warmth, and, as a rule, it will not occur at all if the temperature remains below 10–12° C. The warmer it is, the shorter will be the interval between the male phase and the production of eggs. 'At temperatures of about 20–22° C. each individual oyster may become a female once a year; at temperatures about 14–16° C. every third or fourth year; at lower temperatures still more rarely, and finally not at all.' The more warmth, the more females; and this means greater increase in the stock, always provided that there are sufficient males to effect fertilization. This at once throws light on the fact that in cold waters such as the deep Kattegat and off the west coast of Norway the stock of oysters is much less abundant than in the warmer waters of the Limfjord.

An alternation of sex is known in a number of different animals, such as the slipper limpet (*Crepidula*), the common limpet (*Patella*), the freshwater mussel (*Anodonta*), and one of the small starfishes (*Asterina gibbosa*). A reproductive organ which begins by producing sperms or male elements may after a time produce ova or egg-cells. It seems as if there was an indeterminateness of sex in these types, and that the sex may be swayed in one direction or in the other according to external conditions, which in the case of the oyster are mainly those of temperature. This points to a physiological view of sex, as if it really meant a difference in the rate and rhythm of the chemical routine of the body. In any case the fact is that a male oyster usually becomes female, and that this often becomes male again, the sex see-saw continuing for years under the stimulus of varying temperature.

In Illustration of Snails and Slugs

SNAILS AND SLUGS.—Snails with well-formed shells are represented by hundreds of different kinds in the sea, in the fresh waters, and on land. Slugs, which have little shell or none, are represented in the sea and on land. Together they form the great class of **Gasteropods.** What are their general features?

A few old-fashioned forms, like the *Chitons* which have eight shell-pieces on their back, are *symmetrical*; and we shall leave them by themselves. For all the ordinary Gasteropods are very *unsymmetrical.*

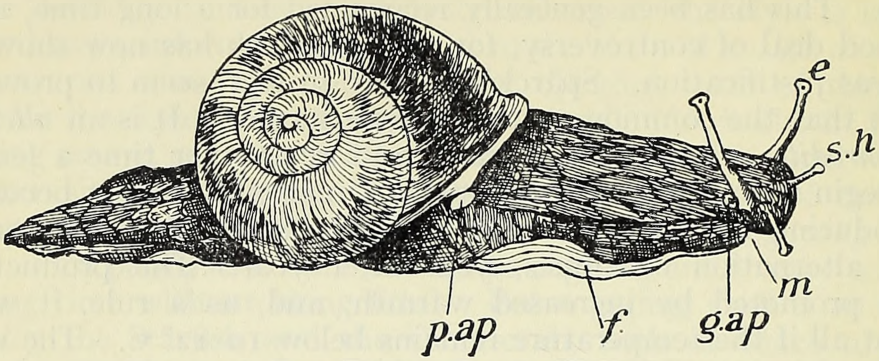


FIG. 152. THE ROMAN SNAIL (*Helix pomatia*)

Note shell covering visceral hump. *p.ap*, pulmonary aperture; *f*, the foot; *g.ap*, genital aperture; *m*, mouth; *e*, eye on long horn; *sh*, one of the short horns.

They are markedly lop-sided animals, for while the head is symmetrical and the muscular foot also, the rest of the body has been deeply twisted to the right-hand side forwards, so that the food-canal ends not far from the mouth. Moreover, there is a pushing-out of the food-canal and digestive gland on the dorsal surface, forming what is called the **visceral hump**; and this has been usually twisted into a spiral and encased, in most of the snails, in a spirally coiled shell. This double twisting of the Gasteropod body is not easily understood, but it is not difficult to see that there is no possibility of cutting an ordinary snail into two symmetrical halves. Yet the '**sea-butterflies**' or 'whale's food' which have become free-swimmers in the Open Sea have become more or less bilateral, as was probably the case with their remote ancestors.

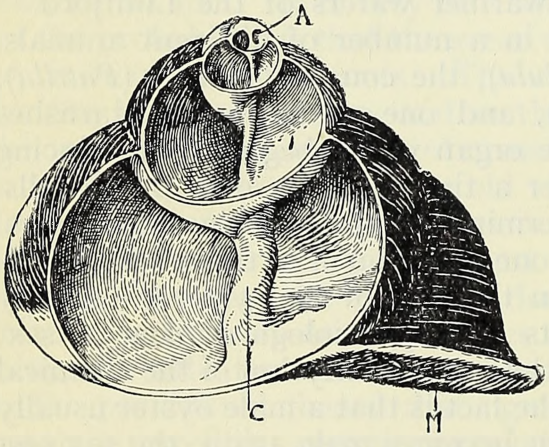


FIG. 153. VERTICAL SECTION OF SHELL OF A SPECIES OF *Helix*

M, mouth of shell; A, apex; C, columella.

Here we may revise the different symmetry possibilities: (1) animals may be radially symmetrical, the same all round, without right and left sides, e.g. jellyfishes; (2) animals may be bilaterally symmetrical, with right and left sides, e.g. earthworm, fish, mammal; and (3) animals may be asymmetrical, like the snails, so lop-sided that they cannot be cut into two mirroring halves.

A Gasteropod differs very markedly from a Bivalve in having a well-developed head. It usually bears **horns** or tentacles and eyes, and there is always a rasping ribbon or **radula** in the mouth.

The **foot,** defined as 'the muscular ventral surface,' is usually a flat creeping sole, within which there lies a gland that makes slime. Every one is familiar with the trail of slime that the garden-snail leaves as it pulls itself along. In the morning we often see where the hungry vegetarian has been exploring at night. In some cases, as in periwinkles, the hind end of the foot bears a lid or **operculum** which forms a neatly fitting door to the shell when the animal draws itself in. It is not to be confused with the land-snail's *fixed* door, the **epiphragm,** which is made of hardened slime and limestone, a door against the winter's cold. The movable lid in the periwinkle or in the whelk is made of organic shell material (*conchin*), but in many cases it is a massive plate of limestone.

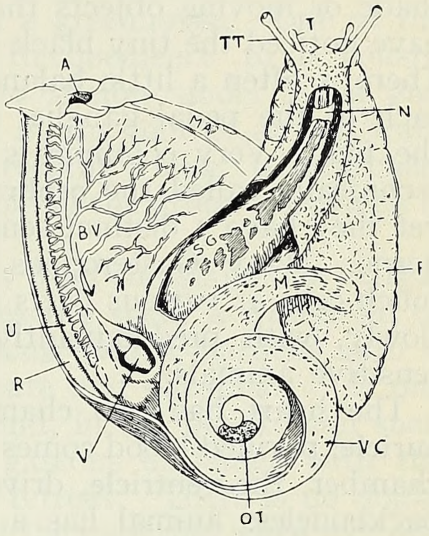


Fig. 154.—Internal Organs of Snail, as Seen in Dissection

T, short horn; TT, long horn with eye; N, cerebral ganglia; SG, salivary glands on the crop; F, foot; M, columellar muscle; VC, visceral coil; OT, ovotestis; V, ventricle of heart; R, rectum; U, ureter; BV, blood-vessels returning from the auricle to the mantle; A, pulmonary aperture; MA, edge of mantle.

The skin-fold or **mantle** is a dorsal cape, thrown towards the head and enclosing a mantle-cavity. This forms a breathing-cavity, usually enclosing a feathery gill bathed in water. In the land-snails the mantle-cavity contains dry air, and the blood-vessels are spread out on its roof. In the majority, the snails, the edge of the mantle makes the **univalve** shell, and adds to its free edge as the Gasteropod grows bigger. Thus there is no need for moulting. In the flabby slugs there may be a **vestige** of a shell, far too small to be of any use. In the common black slug (*Arion ater*) there is not even a vestige. In some cases, like the sea-hare or *Aphysia*, the vestige of the shell has no limestone, but only clear conchin.

In the ear-shell or *Haliotis*, which is an old-fashioned Gasteropod, there are two well-developed gills, but in the great majority the original left gill is lost, as the result of the twisting of the body. Similarly in the limpet or *Patella*, another old-fashioned Gasteropod, there are two well-developed kidneys, but in the great majority the original left kidney is lost.

There are three main paired nerve-centres or **ganglia** in Gastero-

pods, the cerebrals, the pedals, and the pleuro-viscerals, and an interesting point is that they are sometimes very close together, as in land-snails. This means that the nervous system is sometimes concentrated into what approaches a unified brain.

The head of a Gasteropod usually bears eyes, which have a simple structure and are probably of more use for distinguishing light and shade or moving objects than for forming images. Every one must have noticed the tiny black spots at the tips of a snail's longer horns. There is often a little balancing sense-organ (**otocyst**) situated beside each of the pedal ganglia, or, in other words, the nerve-centres of the foot. Very common is a water-testing or smelling sense-organ, technically called the **osphradium.** It is not present in land-snails, yet they have a distinct sense of smell, probably with its seat on the horns. Many Gasteropods have taste-cells about their lips, and touch-cells at various parts of the body. Though they usually move slowly, with predominantly **smooth muscle,** Gasteropods are very sensitive animals.

The heart has two chambers. Into the receiving chamber, the **auricle,** purified blood comes from the breathing organ. The muscular chamber, the **ventricle,** drives the pure blood to the body. When a backboneless animal has a heart, it contains only pure blood, the very opposite of what is true in fishes.

Many Gasteropods have separate sexes, as in periwinkle and buckie; many are hermaphrodite, as in land-snails and sea-slugs. Most of the aquatic Gasteropods show the minute larvae characteristic of Molluscs.

SURVEY OF GASTEROPODS.

(1) The primitive symmetrical *Chitons* with eight shell-pieces on their back. Sluggish marine forms at all depths.

(2) Old-fashioned types, often retaining in whole or in part the left gill and the left kidney, as well as the right: the ear-shell (*Haliotis*), the limpet (*Patella*), and the keyhole limpet (*Fissurella*).

(3) The majority of marine Gasteropods, with a coiled shell and a lid, and separate sexes. They have lost the left gill and the left kidney. Periwinkle (*Littorina*), dog-whelk (*Purpura*), buckie (*Buccinum*). Here are included the free-swimming *Heteropods,* such as *Atlanta,* in some of which the shell has disappeared.

(4) The *Tectibranchs* in which the shell is often reduced, such as the sea-hare (*Aplysia*) and the bubble-shell (*Bulla*). Here are included the Open-Sea *Pteropods,* so-called ' sea-butterflies ' much eaten by whalebone whales, often with reduced shell or none.

(5) The *Nudibranchs* or sea-slugs, without shell, mantle-fold, or true gill, such as *Doris* and *Eolis.*

(6) The land-snails and land-slugs, in which the mantle-cavity is used as a lung, e.g. the common snails (*Helix*), the grey slug (*Limax*), and the black slug (*Arion*). But here are included the common freshwater snails, such as *Limnaea* and *Planorbis*.

THE WINTERING SNAIL.—In late autumn snails become more than usually sluggish and seek out winter quarters. This is an instance of a vital rhythm, for it is exhibited at the proper time even by snails that are kept in the artificial summer of a greenhouse. One of the characteristics of life is **enregistration.** In obedience to a constitutional prompting the snail creeps into shelter under moss and withered leaves or into the loose ground at the foot of an old wall, and there, using the front part of its creeping ' foot ' or muscular ventral surface, it excavates a rounded hole in the ground in which it ensconces itself.

Retracting its head and foot, it secretes from the glandular margin of its skin-fold or ' mantle ' (which makes the shell) a winter lid or **epiphragm.** This consists partly of mucus, which hardens into a membrane, and partly of calcium carbonate and phosphate. If one looks very carefully at the lid, one can find, in the big Roman snail at least, a little chink, through which gaseous exchange with the atmosphere is kept up during the winter retreat. There is no doubt that the lid is protective, for if it is injured the snail dies when exposed to very keen frost, whereas the animal can survive a night's exposure below zero if the lid is quite intact. Having finished the lid, the snail draws itself still more forcibly into the shell, and secretes a number of thin membranes, one after the other. They have their use too, for the air between the papery sheets acts as a non-conductor and conserves the little there is of the precious animal heat.

The word *hibernation* should be kept for those few mammals, like hedgehog and dormouse, which pass into the strange physiological state known as ' winter sleep.' All that one can say of the wintering snail is that it reduces its vital functions to a minimum and lies low, saying nothing. Of course it takes no food, but in a sense it may be said to be *living on its liver.* For it absorbs the stores of animal starch or glycogen which were accumulated in that organ in days of plenty. All the snail needs for about six months in the year is a little oxygen, which seeps in through the chink in the winter lid. That suffices to keep the fire of life burning; or, to put it less metaphorically, the slow combustion of the animal-starch reserves in the liver supplies energy enough to keep the heart beating. In the big edible snail the heart beats on an average about four or five times a minute during the winter rest, a great contrast to the summer rate, which is about ten or twelve, and may rise to much more in midsummer. The wintering snail has learned the difficult lesson that a

reduction of income should be met by a reduction of expenditure. If the experimenter breaks the winter lid and washes the shell in warmish water, the snail may be induced to show itself in mid-winter; but it soon falls ' asleep ' again, and its resisting power is seriously lessened by the interruption. There is much to be learned from the wintering snail.

DOES A SHELL ECHO THE MURMUR OF THE SEA? — Every one knows that when we hold to our ear the spiral shell of one of the large whelks, or ' buckies,' we hear sounds like the echoing cadences of a distant sea. When we were very young we were given to understand that it was the sea we heard, and for many years we accepted this rather pretty fancy. The shells that give the best sea-murmurs are called in Scotland ' roaring buckies ' (*Buccinum undatum*), and are common on many parts of the British coast. Before we press the question of the cause of ' the sound of the sea ' in the shell, let us enjoy again Wordsworth's beautiful lines:

> *. . . I have seen*
> *A curious child, who dwelt upon a tract*
> *Of inland ground, applying to his ear*
> *The convolutions of a smooth-lipped shell,*
> *To which, in silence hushed, his very soul*
> *Listened intensely, and his countenance soon*
> *Brightened with joy; for were heard from within*
> *Murmurings, whereby the monitor expressed*
> *Mysterious union with its native sea.*

Now, the pleasant cadence we hear in the shell cannot, of course, have anything to do with the sound of the sea in which the ' roaring buckie ' lived and made his shell. Echoes cannot be preserved; the shell works quite well in the heart of the country far from the sea; similar sounds can be got from vases, glasses, bowls, and ink-bottles, which have no connection with the sea. It must be admitted that the whelk's shell gives an unusually fine suggestion of waves breaking on a far-off shore, but there is no connection between the sea and what we hear. What is it, then, that we do hear?

No doubt the greater part of the answer is in the word **resonance.** A tuning-fork is often fixed on a box to increase the volume of its sound. When the tuning-fork is struck, the body of the air inside the box vibrates in harmony with the note which the vibrating fork produces. So the body of a violin acts as a resonator for the vibrating strings. But many resonators are so constituted that they respond to certain notes and not to others, or, it may be, to one note only. Thus, from among many sounds or vibrations in the air, the resonator may answer back to only one, which it picks out, as it were, and

intensifies by what is called 'sympathetic resonance.' The tone we hear when we listen to the resonator's vibrations depends on its size, its shape, its composition, and other qualities, as you can prove by holding different kinds of hollow objects to your ear.

To explain how the 'resonance tone' of shells or vases should so differ would be a difficult task. But the fact is that the shell of the 'roaring buckie'—a very fine, and, in its subtleties, inimitable product of a living creature—has its particular resonance tone, as an organ-pipe has. In response to certain vibrations among the many that reach it from various sources, the shell will give out its own resonance tone. And that is the murmur of the sea! But the question remains: What is the particular source of the vibrations to which the smooth-lipped shell resonates? There is no doubt it is sympathetic resonance, but to what?

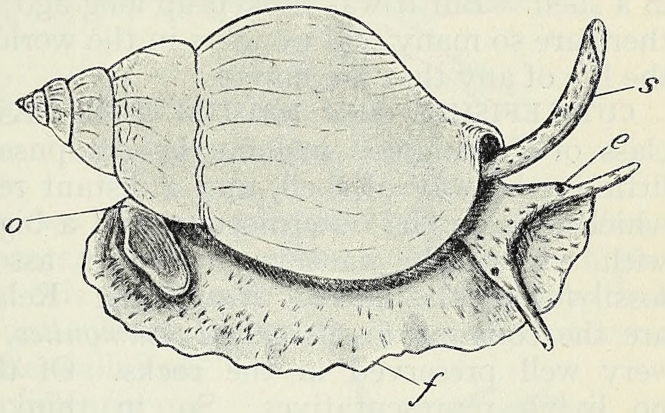


FIG. 155. BUCKIE (*Buccinum*)
e, eye; *s*, respiratory siphon; *o*, operculum; *f*, foot.

We are rather unwilling to give up entirely a long-cherished belief that the origin of the vibrations intensified within the shell may be found partly in activities going on in the body of the listener, but the physiologists assure us that the vibrations in the muscles of the hand, arm, and neck are of little or no importance in the ordinary conditions of listening to a shell. Moreover, the minute air-waves which may be caused by changes in the flow of blood in arteries adjacent to the ear are not of the kind to evoke an answer from the resonating spiral. What, then, are the vibrations the shell picks out and intensifies? They are just those sounds—often inaudible to us—with which the air is usually crowded—sound-waves from a multitude of sources, large and small.

It seems, then, that there are multiplied reflections of very gentle sounds from the curved surface of the polished marble staircase which composes the shell. In much the same way there is a din inside the dome of St. Paul's, because of the reflection of many individually trivial sounds from its internal surface. It is stated that calcareous material has this reflecting power in a marked degree, as soldiers in certain chalk holes in Flanders experienced. The spiral shape of the shell probably improves the murmur, and it is worth remembering that the converse of putting the shell to the ear is to make a trumpet of a

big shell. This is done by boring a hole near the top of the spire, and blowing through it in a certain way. In many parts of the world these **conch-trumpets** have been used for ages. They are often improved by fastening a bamboo cane into the bored hole, and using this as a mouth-piece. In old pictures the sea deities in attendance on Neptune are often represented blowing shell-trumpets. One of the best of the trumpet-shells has *Triton* for its scientific name.

It may seem a pity to break up a pretty fancy about hearing the sea in a shell. But it was broken up long ago; it is obviously untrue; and there are so many real wonders in the world that we need not preserve the life of any that are unreal.

CUTTLEFISHES AND NAUTILI.—The living representatives of the class of *Cephalopods* include the octopuses and squids, which have little in the way of shell, and a distant relative, the pearly nautilus, which lives in the outermost part of a big chambered spiral. Along with the pearly nautilus we must associate a large number of fossil forms, the extinct *Nautiloids*. Related, but not very nearly, are the common fossils called *Ammonites*, whose beautiful shells are very well preserved in the rocks. Of these Ammonites there are no living representatives. So, in thinking of the cuttlefishes of to-day, we must think chiefly of octopuses and squids; it is convenient to leave the pearly nautilus by itself since it is very exceptional.

The Cephalopods are bilaterally symmetrical and free-swimming. They are voracious eaters, particularly fond of crabs and the like, which they tear with a powerful beak somewhat like a parrot's. They are themselves much sought after by toothed whales like the sperm-whale and the bottle-nose. Some of them live at great depths, and have well-developed **luminous organs,** which in some cases seem to be nests of **light-producing bacteria.** Thus many naturalists would say that a fire-fly produces light of its own by a process of rapid fermentation, whereas the deep-sea cuttlefishes owe their luminescence to **symbionts,** the light-producing bacteria.

The foot, which we may define again as 'the muscular ventral surface,' seems to have undergone a remarkable change. Its margin has been divided up into sucker-bearing '**arms**' which have grown round the mouth. In the pearly nautilus they carry, instead of suckers, numerous unsheathed tentacles. But part of the foot is turned into a tubular **funnel** or 'siphon' (incomplete in *Nautilus*), through which water is expelled forcibly from the mantle-cavity, and drives the animal quickly onwards, with its head hindmost. But some of the cuttlefishes can swim quickly with the head foremost, using the posterior body like a propeller that does not go round. The displacement of the water, first to one side and then to the other in rapid alternation, in fishlike fashion, may be helped by muscular finlike

projections. Of course these cuttlefishes are true Molluscs, having nothing whatever to do with Fishes proper.

The muscular mantle lies posteriorly, and encloses a spacious mantle-

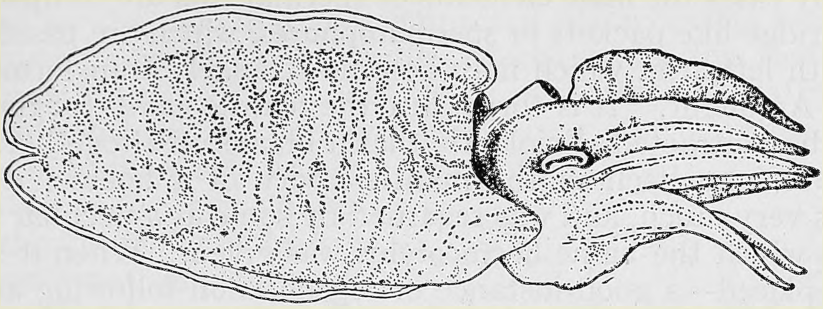


FIG. 156.—SIDE VIEW OF *Sepia*.—After Jatta

cavity, in which there lie the two plumose gills (two pairs in *Nautilus*). There is a wide entrance for water into the mantle-cavity in what might be called the neck region, but this gape can be closed, sometimes with a well-developed double hook-and-eye arrangement. When the entrance is thus closed, and the mantle-walls contracted, the water is forced violently out by the funnel already mentioned, and thus rapid locomotion is effected.

Hidden under the skin on the side opposite the mantle-cavity, there is often a vestige of a shell in the squids and cuttles. In the common *Sepia* it is a broad trowel-like shell of limestone and chitin; in the squid *Loligo* it is a translucent pen of chitin; in *Octopus* there is nothing at all.

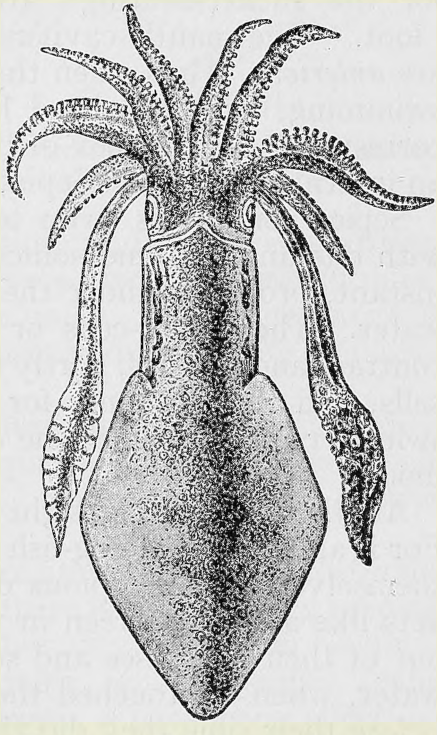


FIG. 157. EXTERNAL APPEARANCE OF A SQUID (*Loligo*)

Cuttlefishes are very active animals and very muscular. Many of the muscles show the quickly contracting kind of muscle fibre, with cross-striping. Besides the muscles used in locomotion there are those that work the arms and the beak, and many other parts. When there are ten arms, as in the common *Sepia*, two are much longer than the other eight, and can be shot out to a considerable distance on the victim. The suckers, sometimes unstalked as in *Octopus*, sometimes stalked as in squids, are muscular cups which take a firm grip, and in the stalked forms their margin is strengthened by a strong chitinoid ring with little teeth. It is not for

nothing that a big cuttle is called a '**devil-fish,**' and there can be little doubt that the hydra-monster with which Hercules contended was a giant Cephalopod.

In many cases the male elements or spermatozoa are compacted into neat cartridge-like packets or **spermatophores,** which are passed out on to the fifth left arm, which may become strangely transformed, as in the male Argonaut. It is thrust into the mantle-cavity of the female, and may be contracted so violently that it breaks off altogether. When it was found by itself in the mantle-cavity of a female, it puzzled zoologists very much, and was regarded by some as a peculiar parasitic worm, to which the name **hectocotylus** was given. When it is lost, it can be replaced—a good instance of **regeneration** following **autotomy.** In most cases, however, the transformed arm is not separated off, but is simply thrust into the mantle-cavity of the female and kept there till the sperm-packets loosen off.

It is not easy to be sure about the various surfaces of the body in a cuttlefish. But if we hold an octopus on a rock with its arms spread out around its mouth it may be said to be resting on its *ventral* surface, for the sucker-bearing 'arms' are believed to correspond to the 'foot.' The mantle-cavity is *posterior* and the cerebral nerve-centres are *anterior.* Thus when the octopus jerks itself through the water in swimming, with the head hindmost, the foremost part of its body corresponds to the apex of the back or *dorsal* surface. When there is an internal shell, as in Sepia, it is towards the *anterior* surface.

Sepias sometimes swim together in little companies, keeping time with one another, and sometimes changing colour almost at the same instant, probably under the influence of some change of light in the water. The colour-cells or **chromatophores** in the skin are able to contract and expand, partly under the influence of surrounding muscle-cells, and this accounts for the flushing and paling of the beautiful swimmers. Sometimes the colour seems to change with the animal's mood.

Another interesting sight is a discharge of ink from the ink-bag. For if an aggressive dog-fish suddenly appears, the cuttles may obscure themselves with a copious discharge of the black waste-product. It acts like a smoke-screen in war. We have taken minute cuttlefishes out of their egg-cases and seen them discharge ink in a bowl of sea-water, when we touched them with our finger-tip. Though hatched before their time they did the fit and proper thing—a **reflex action.**

The Cephalopods should be ranked as the highest backboneless animals, though on a very different line from ants, bees, and wasps. One reason for giving them the first place is the concentration of the nerve-ganglia, into what might be called a compacted brain. In technical language, the cerebral, pedal, and pleuro-visceral ganglia are

close together in the head, and though the result cannot be compared in structure or position to the brain of a backboned animal, it is none the less a notable concentration. It is the **analogue,** though not the **homologue,** of the brain of a shark. The superficial resemblance is heightened by the fact that the compacted nerve-centres are more or less enclosed in cartilage or gristle, which recalls the cartilaginous skull (or gristly brain-box) of such fishes as sharks and skates.

Many cuttlefishes have fine eyes which bear a striking resemblance to the eyes of backboned animals, and here we may learn an important though difficult lesson, that a somewhat similar result may be reached in evolution by quite different paths. The eye of a backboned animal or Vertebrate begins as an outgrowth from the brain, but the eye of a backboneless animal or Invertebrate is rather an ingrowth of the skin. Thus the eye of a fish is quite different in its racial history and in its individual development from the eye of a cuttlefish. Moreover, the *details* of structure are different in the two eyes, though there are at the same time undeniable similarities. When there is superficial resemblance between two structures in unrelated organisms, the term **convergence** is used. The resemblance is due to the fact that the structures or features in question are similarly adapted to the same uses.

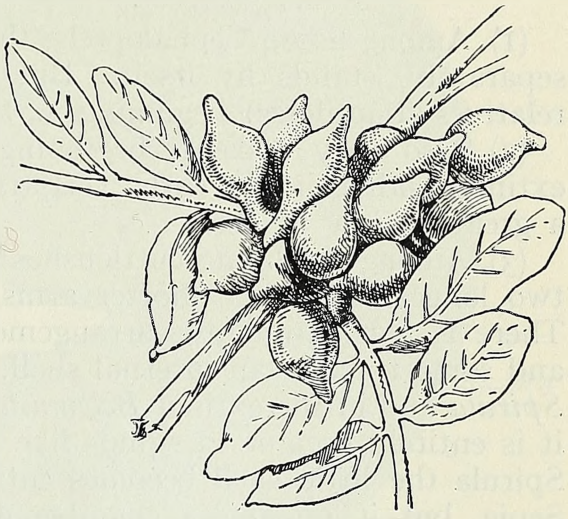


Fig. 158. Bunch of *Sepia* Eggs attached to Plant.—After Jatta

Cuttlefishes are well endowed with other senses. They can smell a dead fish buried in the sand of the aquarium; they are sensitive to touch; they have a balancing 'ear-sac' close to the nerve-centres of the foot.

The mouth is equipped, as we have mentioned, with a chitinous beak, useful in tearing up a victim. But there is also a strong rasping ribbon or *radula* on the floor of the mouth-cavity, just as in Gasteropods. Interesting also is the salivary juice, which, besides being digestive, has in some cases, as in octopuses, a paralysing effect on crabs and other booty.

In ordinary cuttlefishes there are two large feathery gills (Nautilus has four) in the mantle-cavity; there are two kidneys (Nautilus has four); there are two auricles bringing back purified blood to the ventricle or driving chamber of the heart (Nautilus has four).

The eggs are large, well equipped with yolk, and are usually deposited in bunches. The paper nautilus carries them in her shell. From the nature of the eggs it almost follows that there are no larval stages. What comes out of the egg-envelope is a fully formed miniature cuttlefish.

Survey of Cephalopods

(1) Among living Cephalopods, the pearly nautilus, to be discussed separately, stands by itself. But it has a large number of fossil relatives (**Nautiloids**) beginning as far back as the Cambrian.

(2) Also very ancient, beginning in the Silurian, but altogether extinct, ending in the early Tertiary times, are the **Ammonites,** with a great variety of shell.

(3) Among the living cuttlefishes with two gills, the **Decapods** have two longer and eight shorter arms, bearing ringed stalked suckers. There is a hook-and-eye arrangement for closing the mantle-cavity and some trace of an internal shell. This is calcareous in *Sepia* and *Spirula* and in the extinct *Belemnites* (popularly called thunderbolts); it is entirely organic in squids like *Loligo.* In the swiftly swimming Spirula the little shell becomes entirely covered up, just like that of Sepia, but it remains a chambered spiral. In Nautilus the animal is inside its shell; in Spirula the shell is inside the animal.

(4) But the living cuttlefishes with two gills also include the **Octopods,** with only eight arms. Their suckers are not stalked and have no chitinous ring. There is no hook-and-eye arrangement for closing the mantle-cavity and there is no internal vestige of a shell. *Octopus* and *Eledone* are two common examples. Here is included the paper nautilus or *Argonauta,* in which the female is much larger than the male and lives in a beautiful shell, which also serves as a cradle for the eggs and young ones.

THE PEARLY NAUTILUS.—If we did not belong to a race of organisms that has anatomized the pearly nautilus and inquired into its history, we might well be proud to belong to the race of Nautiloids. For it may be doubted whether there are any edifices more perfect than theirs, and to some extent an organism may be judged by the home it makes. And among the Nautiloid shells the most exquisite is that made by the only form that now survives, *Nautilus pompilius* and other species, the pearly nautilus. As Walt Whitman says, ' it would adorn the parlours of heaven.'

It must be admitted, of course, that animals do not put either blood and tears or smiles and joys into their creation of beauty, as a human

artist might do, yet what they make is in some measure an expression of their inmost nature. Perhaps the most beautiful shell in the world is that of *Stephanotrochus*, a solitary Deep-Sea coral, a squat, brainless sea-anemone living in eternal night. Yet this coral's house, which may also be its unending dream, is indescribably exquisite. Finer than Venus's flower basket (so beautifully woven that we call it *Euplectella*), the shell of Stephanotrochus, which its builder never sees, which few people in the world have ever seen, might worthily serve as a chalice for Titania.

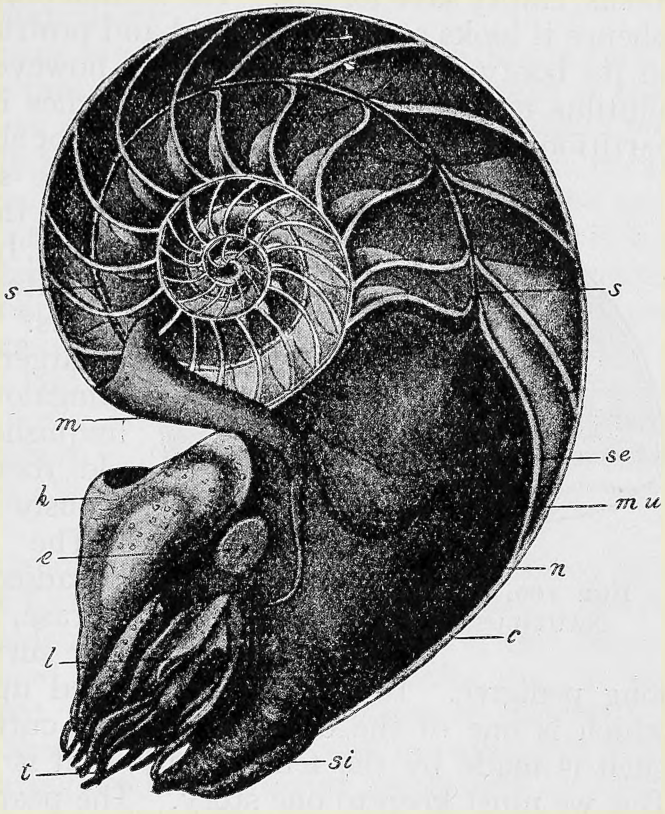


FIG. 159. THE PEARLY NAUTILUS (*Nautilus pompilius*).—After Owen

The shell is represented in section, but the animal is not dissected. Part of the mantle has been removed. *c*, body chamber; *se*, septum; *s*, siphuncle, a tube by which all the compartments communicate; *m*, portion of mantle; *h*, hood; *e*, eye, with its opening to the exterior; *l*, lobes bearing tentacles (*t*); *si*, the incomplete siphon; *mu*, shell muscle; *n*, position of nidamental gland.

If we are right in supposing art to be the expression of an idea or an emotion or a desire in some significant medium, we cannot credit animals with much more than **unconscious art,** which comes perilously near a contradiction in terms. Perhaps a chaffinch or a weaver-bird or a long-tailed tit or a sea-swift approaches art in making its nest, expressing in it something of its *joie de vivre*, but what are we to say in regard to the shell of the pearly nautilus, which seems to take form out of the creature's physiological harmony, almost as a crystal does out of the saturated solution? It is very difficult to use such a phrase as 'the skilful use of material' when the process of construction does not seem to require control, and when it is, as regards consciousness, as far below the wasp's nest or the bee's honeycomb as either of these is below the bower-bird's bower, or that below the Taj Mahal.

When it is smaller than a split pea, the pearly nautilus secretes a

tiny cup of limestone. As it grows a little bigger, the creature makes another room of slightly larger size, and draws itself forwards. It continues this growing and building month after month, year after year; and a median section of the shell shows the spiral succession of rooms, empty save for gas. The animal occupies the largest and latest, whence it looks out on the world and protrudes its numerous tentacles on its booty. It should be noted, however, that when the growing nautilus makes a new room and hitches itself forwards, the curved partition that marks its advance does not shut off more than a portion of the space previously occupied. Thus the succession of compartments, lying in one plane in a spiral, indicates the closure of *parts* of rooms. It is as if a man, in adding a larger room to his one-roomed bungalow, partitioned off and relinquished only a fraction of the old room in which he had previously lived.

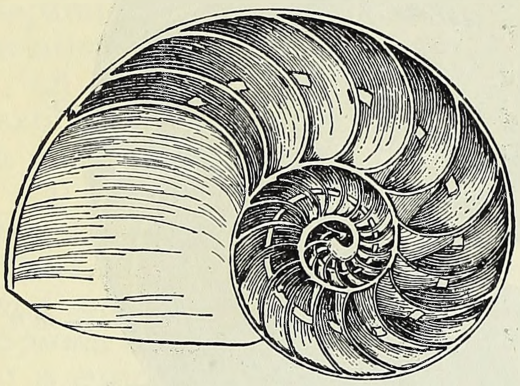


FIG. 160. SECTION OF SHELL OF NAUTILUS.—After Lendenfeld

The pearly nautilus is often paradoxically called, in Darwin's phrase, 'a living fossil,' for it is the sole survivor of an extinct race of long pedigree. It is not to be mixed up with the paper nautilus, which is one of the distantly related cuttlefishes. In this type the shell is made by the female only, and is not a house, but a cradle. But we must keep to one story. The pearly nautilus, represented by three or four species, is at home in the seas of the Far East, such as those washing the Moluccas and the Philippines, New Britain, New Guinea, and Fiji. It is fished for by the natives, who like the flesh as a change. Traps are set at a depth of thirty to seventy fathoms, and baited with small soft-skinned fishes. The exposed part of the animal is dark brown and mottled white, and the shell shows somewhat ripple-like zebra markings. Professor Willey has suggested that the colouring is protective, hiding the nautilus from the hungry eyes of sharks and congers or other enemies. The males can be distinguished from the females by a slight difference in the mouth of the shell.

When we consider the large size of the shell, we cannot but be surprised at the fact that the nautilus is an expert and rapid swimmer. Indeed, swimming (by jerking out jets of water) is its usual means of locomotion. Inquiry shows, however, that besides being compactly built, with an admirable combination of economy of material with strength, the shell is very buoyant. The vacated compartments,

connected with the animal by a membranous tube called the *siphuncle*, form an air-tight and water-tight system containing secreted gas with more nitrogen than in atmospheric air. As the shell becomes bigger it also becomes more buoyant, until the final large chamber is formed, an event that indicates maturity. The total number of compartments is often about thirty.

Unlike the paper nautilus or argonaut, the pearly nautilus is rarely seen at the surface. Those that have been observed or caught at that level are to be interpreted as moribund. Yet it must be noted that, while the nautilus habitually feeds on or near the floor of the sea, it can shift its quarters quickly, and Dr. Willey remarks that it may be seen swimming about in water only a few fathoms deep. Habitually it is a night-feeder, and depends largely on shrimps and similar crustaceans, which it finds in sea-gullies at a depth of thirty to seventy fathoms or more. It has a healthy appetite.

The eggs are apparently laid singly in separate capsules, and what comes out of the egg is not a larva, but a well-formed miniature nautilus, with several chambers in its little shell. But the aristocrat appears to be reluctant to allow even respectful zoologists to peer into its family affairs.

It is possible that Aristotle knew the pearly nautilus, but it was first recognizably described and figured (in 1705) by Rumphius, a Dutch physician and botanist, resident in the East Indies. As this record was for the most part ignored, it is interesting to notice that it was about a hundred years ago that Dr. George Bennett captured a floating specimen off the New Hebrides. It was he who said that the remarkable object floating upon the water resembled 'a dead tortoiseshell cat.' Bennett gave his prize to Sir Richard Owen, who published a famous memoir on it in 1832. Much has since been discovered in regard to one of the most notable of animals, but what Willey said in 1902 remains to be confessed afresh, that it will be long before this Pierian spring is exhausted. Long live the veteran nautilus!

THE ARGONAUT'S CRADLE.—On his *Arcturus* voyage, Mr. Beebe watched the female paper nautilus or argonaut in a temporary aquarium. She was in an explosive temper when she was put into the tank, and effaced herself in a cloud of sepia. Indeed, she had to be transferred twice before she had emptied her ink-bag and could be clearly seen. 'She rested quietly on the bottom with her many arms wrapped about her beautiful brown and white shell. But, as soon as my face approached the glass, she rushed back and forth, shooting directly at me or bumping against the opposite glass, and, finally, backing into a corner.' She eventually condescended somewhat ungraciously to accept a small fish, which she ate. In all probability

some parental anxiety complex made her furious, for, two days later, in a paroxysm of rage, she flung herself clear out of the shell, which is, of course, rather a cradle than a house. It is not represented at all in the much smaller male, and, instead of being secreted by the 'mantle' as in other molluscs, it is made by two flat plates on two of the arms—the two arms which some of the old naturalists believed she held aloft as sails to catch the wind. Mr. Beebe found thirteen hundred eggs in the shell, each about ten millimetres by fifteen, tied loosely together like miniature bunches of grapes. Some of them were well advanced in development and showed the embryo argonauts with two relatively large red eyes.

USES OF CUTTLEFISHES.—The idea that everything is made for man (the anthropocentric myth) dies hard; but the zoologist is not pestered as he used to be by demands for information in regard to the *uses* of wasps and house-flies and daddy-long-legs, and so on up to cuttlefishes and beyond. The truth in the myth is, no doubt, that man is the crown of creation—giving additional meaning to the great work of art—and that deep and extensive foundations have, as a matter of fact, been laid that have made the human superstructure possible. It is beyond science to say that the myriads of water-fleas in the ocean, more in a bucket than we can see of stars on a clear night, are there *in order to* feed the fishes; but it is a fact that they make the continuance of fish-life possible, just as fishes do the same for fishermen. The misleading part of the myth is the idea that every living creature must justify itself at the tribunal of man's needs and desires, comforts, or even luxuries. Every organism has its place in the *systema naturae*, but it does not follow that the circle of its life will intersect man's, either for good or ill.

Yet, with increasing knowledge of the importance of even slender threads in the web of life, we see that many creatures have an unsuspected utility. Thus Gilbert White and Charles Darwin proved that earthworms have been among the most useful animals in the world; and so, to mention little things after great, it was not till we read Sir Arthur Shipley's picturesque book on *Islands* (1924), that we realized the manifold utility of cuttlefishes.

No doubt cuttlefishes, which, we repeat, are *Molluscs*, sometimes devour true fishes, but they do not confine themselves to the kinds man likes. Much more important is the fact that cuttlefishes are edible—sometimes even palatable. They are handy during Lent, when fish is forbidden as well as flesh. Sir Arthur Shipley, who re-sampled them recently, quotes Plutarch to the effect that 'both the octopus and poetry are delicious food, but must be partaken of with moderation, for they are both apt to cause bad dreams.' The sepia-bone or cuttle-bone, a vestige of an ancestral shell, often given to cage-birds to

peck at, is made into pounce and tooth-powder and moulding material for casting precious metals.

In one of his charming essays Mr. P. G. Hamerton wrote of the service done by the pig to the fine arts, for the bristles make good brushes for oil-painting; and we may include the cuttlefishes in the same honourable service, inasmuch as they produce sepia in their ink-bags. They use it to baffle the sharp eyes of sharks, but the material is still prepared for the painter who makes light out of its darkness. We believe, however, that most of the modern sepia has no flavour of the sea.

We are lingering over these cuttlefishes, but Sir Arthur Shipley tells us two extraordinary things about them that we must pass on. 'A former British Chaplain at Yokohama states that these molluscs are apt to make inland raids on the potato patches, for they are said to be extremely fond of this tuber.' Well, well! The other story is that the Cretans use the octopus to pick up lumps of coal from the adjacent waters where deposits accumulated during the war. 'Not being mechanically minded, and being devoid of dredging apparatus, the Cretans retrieved this treasure by attaching an octopus to a string and lowering the mollusc over the coal-dump. As soon as it had attached itself by its tentacles to its resting-place, they gently pulled it up; the adhering lump of coal was then detached, and the octopus dropped in again.' The cuttlefish as coal-heaver? What was it Epimenides said about the Cretans?

Conchology

THE STUDY OF SHELLS.—One of Father O'Flynn's many accomplishments was conchology, and it is a hobby to be recommended. For shells are safe from the tooth of time, which is more than can be said of butterflies and bird-skins which mites gather together to devour. Shells require no preservation and stand in sharp contrast to the museum's fishes, which are usually so dismal. Shells are altogether beautiful in form and often in colouring, and, being products of living creatures, they have that touch of individuality which one misses in minerals. Cabinets of shells have gone out of fashion, but that is not to our credit, for they are beauty-feasts; and it is no sign of progress when there is a waning in man's delight in beautiful things.

The mollusc's shell, such as that of a pearly nautilus, a cowry, an olive, a cone, a harp, a scallop, a cockle, a venus, or a circe, is a product of a fold of skin called the 'mantle,' and consists of platelets of calcium carbonate laid down along with an organic matrix called *conchin* or *conchiolin*. Its size can always be added to at the free edge as the

tenant grows larger, and thus the inconvenience of moulting, which is characteristic of crustaceans and other jointed-footed animals, is obviated. As the increase in size is periodic—an addition and then a pause, there arise the parallel lines which add so much to the beauty of shells. They are indeed the ripple-marks of growth and reveal something of the ups and downs in the creature's life, just as is the case with the markings on the scales of salmon and other fishes, and to some extent with our own finger-nails. We wonder that a credulous age has not made more of onychomancy or nail-divination !

The simplest Gasteropod shell was probably conical or limpet-like, but as the dorsal rupture or protruding hump of the internal organs became more pronounced and sagged to one side, the shell-making would tend to accommodate itself to the asymmetry and result in a spiral. We must not suppose, however, that the limpet's conical shell represents the ancestral simplicity, for the youngest stage in the limpet has a spiral twist. The limpet's simplicity of conical form is secondary, not primary. And here we may mention the instructive fact that the limpet form of shell has been assumed in at least five quite distinct types, and approached in many others. The fact is that the shape of the shell is no proof of blood-relationship. Evolution often repeats itself.

The typical Gasteropod shell is well represented by the buckie or whelk which children hold to their ears, to hear the supposed reverberation of the distant sea (p. 398). This whelk shell or any other like it is a single-chambered spiral, and no part of it was empty during the animal's life. It is a right-handed spiral. If we hold it with the apex of the spire upwards and away from us, and the mouth of the shell towards us, then the mouth will be to our right hand. If we thought of walking up the spiral, as if it were a wide staircase, we should have the axis of the stair always to our left. To this central pillar the Gasteropod is attached by means of muscles which draw the exposed parts into shelter; and here it may be noticed that an inturned projection, like a shelf in the slipper limpet and like a funnel in the crucible shell, sometimes serves to keep the animal within the shell when there is, as in these cases, almost no spire. In a few Gasteropods the normal shell is left-handed or sinistral, and this condition may occur as an abnormality in types usually dextral—a good instance of a superficial freak or mutation. It is instructive to walk round the shelves of Gasteropods in a good museum, just to realize the number of variations on a simple theme, the spiral shell of a snail. The spire may be elongated like a slender turret, as in the auger-shell; or broadened out flatly, as in the ear-shell; it may develop in one horizontal plane, as in the freshwater *Planorbis*; it may loosen out so that the whorls cease to touch; and the spiral character may

be masked or hidden as in cone-shells and cowries. This is Nature's way, to play the same tune with many variations.

Quite different from the spiral shells of Gasteropods are those of Ammonites and many other extinct Cephalopods. For these are chambered shells, in which the animal lived in the outermost chamber of its house, the others being empty. They are also bilaterally symmetrical shells, and lie in one plane. The only living Cephalopod that shows this type of shell is the pearly nautilus; but the little Decapod cuttlefish called *Spirula* has a loosely coned chambered spiral which is for the most part concealed by overlapping folds of the skin or mantle. This is a very interesting relic of the more or less spiral shell possessed by extinct ancestors. But one cannot say that the Spirula lives in it, for it is inside the Spirula. The house is inside the builder.

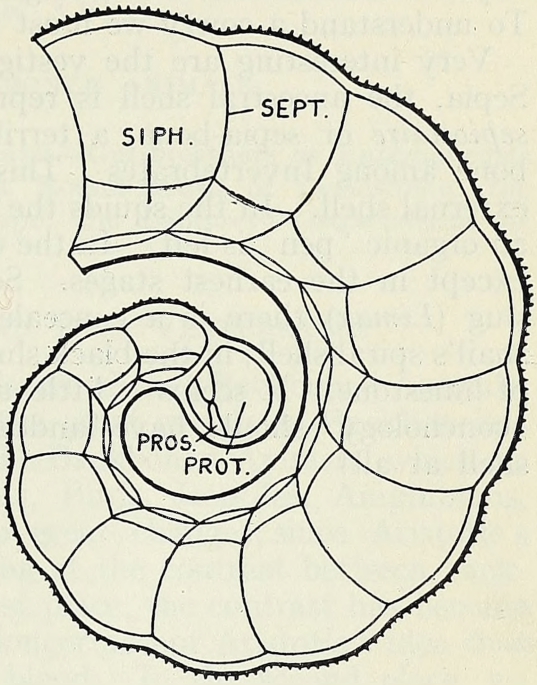


Fig. 161. Section of the Shell of *Spirula*

SEPT, septum; SIPH, siphuncle; PROT, protoconch; PROS, protosiphon.

There are some very peculiar molluscan shells. Thus in the primitive bilaterally symmetrical *Chitons* the shell is represented by eight dorsal plates which overlap one another like the tiles on a roof. The plates are perforated by sense-organs, and the animals always keep out of the light. If they are lifted they roll up into a ball after the manner of some wood-lice and armadillos. Little ones —an inch long or less—are common on British shores; but they are also represented at great depths. Some giants are over six inches in length. These Chitons are very ancient, going back to the Silurian, and they are very old-fashioned. Somehow they do not look like Molluscs, for the eight valves suggest segmentation.

In the ship-worm or *Teredo*, a quaint boring bivalve, the two valves are small and are continued into a long limestone-lined tube, leading from the recesses of the timber to the surface, where two breathing-siphons project. In the still stranger sand-burrowing watering-pot shell (*Aspergillum*), a puzzle for advanced students of zoology, there is a somewhat similar calcareous tube, but substantial and rigid, whose anterior end is perforated like the rose of a watering-can. But

in this case the two valves are present in neat miniature, and actually soldered to the outer wall of the tube.

A shell that is difficult to understand right away is the familiar shell of the cowry. When it is young it is a rather thin spiral shell with a prominent apex. But as it grows it becomes almost surrounded by two larger lobes of the mantle, which make secondary deposits of limestone, embedding the spire and finally hiding it entirely. To understand a cowry we must break it.

Very interesting are the vestigial or dwindling shells. Thus in a Sepia, the ancestral shell is represented by the internal calcareous *sepiostaire* or sepia-bone, a terribly wrong name, since there is no bone among Invertebrates. This 'sepiostaire' is a relic of the old external shell. In the squids the limestone has disappeared, and only an organic 'pen' is left. In the octopus there is no hint of any shell, except in the earliest stages. So, among Gasteropods, in the grey slug (*Limax*) there is a concealed thin plate, which represents the snail's spiral shell; in the black slug (*Arion*) there are only a few grains of limestone. It seems a little unfortunate that our little study of 'conchology' should have landed us in molluscs with practically no shell at all!

CHAPTER XVI

BORDERLINE BACKBONED ANIMALS

Primitive Chordates and true Vertebrates—Gut-breathers or Enteropneusts—Tunicates or Ascidians—Lancelets—A Round-mouth or Cyclostome: the Glutinous Hag—Another Cyclostome type: the Lamprey—Ostracoderms or Hypostomes.

Primitive Chordates and True Vertebrates

Two thousand years ago Aristotle discerned that Backboned Animals, as we call them, stand apart from the great variety of Backboneless Animals. He also recognized that the Backboned Animals, which he called 'blooded,' included Mammals, Birds, Reptiles, Amphibians, and Fishes. There have been two great changes since Aristotle's day in the naturalist's way of looking at the contrast between backboned and backboneless. In the first place, the contrast has become much more precise, and we can no longer accept Aristotle's idea that the backboneless animals have no blood. In the second place, we know that there are borderline classes below the level of fishes. These are:

(1) The Gut-breathers or *Enteropneusts.*
(2) The Ascidians, Tunicates, or Sea-squirts.
(3) The Lancelets, especially *Amphioxus.*
(4) The Round-mouths or *Cyclostomes,* though some zoologists would rank these with ordinary fishes, such as skate, shark, haddock, and salmon.

When we think of the whole series or phylum of animals from the worm-like Gut-breathers or Enteropneusts up to Man, we use the technical term **Chordate.** This means that they almost always possess a supporting rod or skeletal axis called the **notochord.** But when we think of Fishes, Amphibians, Reptiles, Birds, and Mammals, which possess a backbone built up of separate pieces or vertebrae, we use the term **Vertebrate.** Thus the group of Chordates includes (*a*) the Primitive Chordates, and (*b*) the more definite Chordates or True Vertebrates. All Vertebrates are Chordates, but not all

Chordates are Vertebrates. To make this point quite clear, let us put it thus:

- GROUP or PHYLUM CHORDATES
  - (*b*) **True Vertebrates**
    - *Mammals*
    - *Birds*
    - *Reptiles*
    - *Amphibians*
    - *Fishes*
  - (*a*) **Primitive Chordates**
    - *Cyclostomes*
    - *Lancelets*
    - *Ascidians*
    - *Gut-breathers*

As we have admitted, some zoologists—perhaps most—would place the Round-mouths, like the lamprey and the hag, beside Fishes, and therefore among True Vertebrates, whereas we are inclined to keep them at a lower level among the Primitive or Old-fashioned Chordates. As we shall explain, they differ from fishes in several very important respects, such as the absence of jaws and limbs. It is easy to understand that there may be room for difference of opinion in regard to the boundary lines between the groups into which we divide related animals.

Let us now inquire into the salient features that distinguish the Chordates from the non-Chordates, or, less precisely, the *Backboned* or **Vertebrate** from the *Backboneless* or **Invertebrate.** These may be arranged in parallel columns, and to save space we shall represent Enteropneusts, Tunicates, Lancelets, and Cyclostomes by the letters E, T, L, and C.

	Non-Chordates (Backboneless)	**Chordates (Backboned)**
I.	If there is a nerve-cord it is *ventral.*	The central nervous system—the brain and spinal cord—lies *dorsally,* and has a ciliated canal down the centre. (In E and L there is no distinct brain.)
II.	There may be much in the way of external skeleton, but there is never any hint of an internal dorsal axis.	There is a dorsal supporting axis, called the notochord, in the embryos at least, but this is usually replaced by a segmented backbone. (In E the notochord is very doubtful; in T it is confined to the tail; in most Fishes and in all higher forms it is a vestige except in the embryos.)

	Non-Chordates (Backboneless)	Chordates (Backboned)
III.	Backboneless animals breathe in a great variety of ways, but there are no ' gill-clefts.'	' Gill-clefts ' open from the pharynx—the beginning of the food-canal — to the outside world, and are used in connection with breathing till Reptiles are reached. In all Fishes and in young Amphibians at least the clefts are accompanied by gills. In higher forms there are no gills, and the gill-clefts are transitory and functionless, except when transformed into something very different.
IV.	If there is an eye it is mainly derived from the skin, developing from without inwards. A ' skin eye.'	The essential back part of the eye, including the retina, arises as an outgrowth from the brain. This outgrowth continues till it meets the skin of the embryo, which forms a lens in front of the eye-cup. A ' brain eye.' But it must be noted that the brain arises in the embryo as an insinking of the embryonic skin. There is no eye in E or L.
V.	If a backboneless animal has a heart, as in lobster, beetle, spider, mussel, or snail, it is a *dorsal* heart.	The heart is on the *ventral* or under-side of the body, which in man, standing upright, is called the anterior. There is no heart in E or L.
VI.	Many backboneless animals, such as earthworms, sea-worms, lobsters, insects, and scorpions, have *segmented* or ringed bodies. But many are unsegmented, as in jellyfishes, round worms, starfishes, and molluscs.	The body of the Vertebrate is typically *segmented*, as is indicated by the backbone-bodies or vertebrae, by the muscle-blocks seen in embryos and persistent throughout life in most Fishes, in the way in which the nerves come out from the brain and spinal cord, and in other ways. There are no clear segments in E or T.

It is worth noticing that if we take a good representative of the backboneless animals, say a lobster, and turn it upside down, the change of position brings its nerve-cord to the upper-side and its heart to the under-side, *and this is how they lie in backboned animals.* So it has been seriously suggested that Vertebrates may have evolved from inverted Invertebrates, which took to swimming on their back. Perhaps these pioneers were worm-like animals.

If we accept the evolutionist way of looking at living creatures, we must suppose that Chordates arose from non-Chordates, but their precise origin remains quite uncertain; we do not know where to fit them on. The clue has not been discovered as yet. But if we ponder over this problem there are two things to keep in mind. First, we must not think of the origin of the well-defined backboned animals or Vertebrates, from Fishes onwards; we must think of much more old-fashioned and primitive Chordates, such as the Lancelets or the young Tunicates. Second, we must not try to link these primitive Chordates back to very complicated non-Chordates which have gone far along some particular line, as in the case of King-crabs, for instance. In other words, we must not look among highly *specialized* Invertebrates for hints of the ancestry of Vertebrates. We must look among *generalized* types, which have not become extremely complicated. Thus many zoologists have sought to link Vertebrates back to Ringed Worms or Annelids.

Gut-breathers or Enteropneusts

There is a small class of worm-like marine animals, technically called **Enteropneusts** (*enteron*, gut or food-canal; *pneusts*, breathers), because they have gill-slits opening from near the beginning of the food-canal to the outside world. As no backboneless animals ever breathe in this way, most zoologists believe that the Enteropneusts are survivors of primitive forms that diverged from near the origin of the Chordate stock. Though probably not on the direct line of ascent, they are intermediate types—illustrative of the connecting-links which are supposed by some people to be always missing. The Enteropneusts are either Chordate-like worms, or worm-like Chordates.

In addition to the **gill-slits**, through which water passes, there are some interesting features in these Enteropneusts. Thus, along the dorsal middle line there is a slender nerve-cord, in the same position as the Vertebrate's spinal cord. It must be noted, however, that this dorsal cord is connected, by a ring round the pharynx, with a ventral nerve-cord; that is to say, a cord in the typical position for all the Invertebrates that have nerve-cords. Moreover, in the ciliated skin there is a loose network of nerve-cells and nerve-fibres. Thus we might

say that there are two middle-line concentrations of what is otherwise scattered.

The worm-like body has three regions: (1) a pre-oral muscular proboscis, which is used for burrowing in the sand or mud; (2) a firm 'collar' region, around and behind the mouth; and (3) a trunk, which may be six inches long, with gill-slits in its anterior portion. From the front of the food-canal a little rod grows forwards, for a short distance, into the proboscis. This is often compared to the supporting axis or **notochord** in a primitive Chordate animal like a lancelet or a lamprey. If the comparison be admitted, there are in Enteropneusts three Chordate features:

Indubitable gill-clefts;
a dorsal nerve-cord;
and a sort of 'notochord.'

Another reason, though a very technical one, for linking the gut-breathers to the undoubted backboned animals, such as fishes, is the way in which the **body-cavity** or **coelom** arises. It will be remembered that this is the space between the gut and the body-wall, always lined by the median germinal layer or **mesoderm**; and the point is that this arises in Enteropneusts in the form of five pocketings from the embryonic gut. This is just the way in which the body-cavity arises in lancelets, which are undoubted Chordate animals. This correspondence is a straw that shows, we think, how the evolution-wind has blown.

The Enteropneusts burrow in the sand and mud, usually in shallow seas; and they are well represented in some lochs on the west of Scotland. They have a wide geographical distribution, which is to be expected in old-fashioned types which have had many ages in which to colonize the seven seas.

They feed on minute organisms and particles, forced along with the sand or mud into the hardly closable mouth. Their movements are leisurely, and their muscle-fibres are of the slowly contracting **unstriped** type. A good deal of slime is exuded from the skin, and this is probably unpalatable. In many cases there is a strong and peculiar odour, suggesting the antiseptic called iodoform. There must be some protective features, one would think; otherwise such soft-bodied animals would have been all eaten up long ago. The colours are often bright, and some of the three dozen or so species are luminescent. If the body is broken, the lost hind portion can be readily regrown, thus illustrating **regeneration.**

The sexes are separate and the minute eggs are fertilized in the water. It is interesting to find that some kinds have a **direct development,** that is to say, there is a gradual building-up of the adult form,

while others show an **indirect development**, that is to say, there is an interpolated larval stage (called the **tornaria**) that swims freely in the Open Sea. Among the common kinds may be mentioned *Balanoglossus*, *Dolichoglossus*, *Ptychodera*, and *Glandiceps*.

A student is sometimes apt to be impatient when his guide lingers over such 'unusual rarities' as Enteropneusts. But they are much commoner than is often supposed, and in certain places at certain times they may occur in prodigal abundance. Who ever heard of *Glandiceps*? But listen to this little story from Japan.

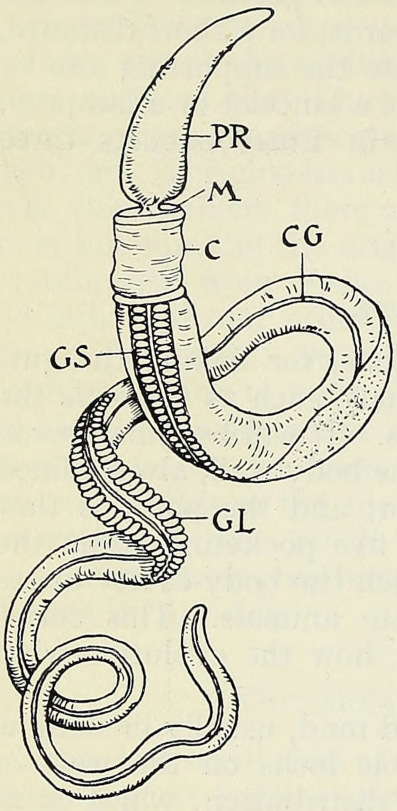


FIG. 162. *Balanoglossus*
PR, proboscis; M, mouth; C, collar; CG, ciliated groove along dorsal middle line; GS, gill-slits; GL, glandular sacculations of the food-canal, shining through the skin.

Professor Iwaji Ikeda writes: 'Very early in the morning of 3rd September 1907, when I was out skimming with some of my students off Sesuijama (near Torno, about fifty miles east of Hiroshima) in the Inland Sea, a curious sort of plankton (drifting living creatures), covering a considerable area, attracted our notice. On examining the contents of our net, it turned out to be swarming *Balanoglossus*. A little later, when the sun was about to rise, we could perceive myriads of lively swimming specimens about our boat. We now came to realize that we had been rowing about in a big sheet of swarming Enteropneusts. More than delighted with this sight, we collected a bucketful of specimens—a task accomplished in but a minute. They measured from three to fifteen centimetres in length (eight centimetres on an average—rather over three inches). The belt-like zones of this plankton varied from one to five metres in width and were in some cases two metres in thickness. The animals were crowded in various degrees; at the thickest spot about fifty individuals in a cubic foot of water, while at the thinnest only about ten in the same. After nearly a hundred yards' row, we came across another broader sheet of swimming Balanoglossus. There they were so thick that we could count nearly a hundred specimens in a cubic foot of water. When the sun was up, this curious phenomenon almost suddenly disappeared. On coming back to shore, we found, to our great surprise, a considerable stretch of the beach, a metre in width, covered with the deep reddish-brown Enteropneusts.'

We have quoted this interesting passage because it illustrates the prodigal abundance of a relatively unfamiliar kind of animal, but it also illustrates a divergence from the usual Enteropneust habit of burrowing and sand-eating. The species in question, *Glandiceps hacksii* by name, is sometimes a swimmer near the surface and sometimes a creeper on the sea-floor. Its posterior body is much flattened and the margins serve as fins in the swimming. In the Japanese specimens the food-canal contained no sand, but compacted masses of diatoms (single-celled plants) and infusorians (single-celled animals). To obtain this food the Glandiceps comes to the surface in calm summer mornings before sunrise.

Apparently allied to Enteropneusts are certain remarkable colonies called *Cephalodiscus*, first found on the **'Challenger' Expedition** at the Straits of Magellan. Minute individuals are associated within a somewhat gelatinous investment. The detailed structure shows many points of resemblance with Enteropneusts, e.g. gill-slits (only a pair), a dorsal nervous system, a slight hint of a notochord, and a three-pocketed body-cavity.

Another, probably allied, genus is *Rhabdopleura*, found at considerable depths in the North Sea and the Atlantic. Minute individuals are united in a colony, but they are definitely attached to one another, not simply imbedded in a common investment, as is the case in *Cephalodiscus*. There are five body-cavity pockets and there is a hint of a notochord. But there are no gill-slits.

More remote are two tubular animals, *Phoronis* and *Phoronopsis*, with a horseshoe crown of tentacles and many peculiarities. Some zoologists place them near *Cephalodiscus* and *Rhabdopleura*; others think that their relationships are with the moss-animals (*Bryozoa* or *Polyzoa*). Mere mention is all that these rarities can have in a book like this, but we think that the mention is useful in indicating that there are several distinct kinds of animals near the very important border-line between the backboneless and the backboned.

Tunicates or Ascidians

These common marine animals, popularly called 'sea-squirts' and technically *Urochorda*, form a large class of primitive Chordate animals. Most of them are sedentary, after their free-swimming larval life is past, and most of them undergo 'retrogressive metamorphosis.' They begin well and end ill; they are Chordates in their youth, usually nondescripts when they become adult. Except the few that retain their larval characters throughout life, e.g. *Appendicularia*, they illustrate individual **degeneration.** No anatomist, however adept, could

have recognized a typical Ascidian as near the threshold of Vertebrate life, but in 1866 the Russian naturalist Kowalevsky traced the life-history and showed that the *development* of a typical Ascidian has a very close resemblance to that of the lancelet. This is a good instance of the light that embryology can throw on the position of a type in the classification. Another good example is to be found in barnacles, whose affinities were uncertain until the *development* was worked out by J. Vaughan Thompson in 1830.

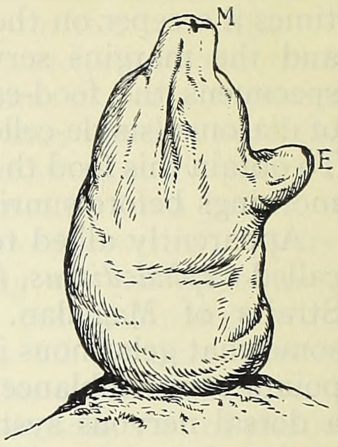


FIG. 163. EXTERNAL APPEARANCE OF AN ASCIDIAN OR SEA-SQUIRT
E, exhalant aperture; M, mouth.

GENERAL CHARACTERS. — Tunicates are marine Chordates, occurring from the shallow water of the shore to the Open Sea, and also to the great abysses. After the larval stages, which are pelagic, the great majority are sedentary, but some remain free-swimmers. The larval forms, along with a few types which do not degenerate, show the following Chordate features: a dorsal tubular nervous system, a notochord of a simple sort in the tail region, gill-slits opening from the pharynx to the exterior, an eye developing as an outgrowth from the brain, and a ventral heart. In the course of the retrogressive metamorphosis the nervous system is generally reduced to a single ganglion situated above the pharynx; the gill-clefts become secondarily very numerous and open into a chamber (the *atrium*) which communicates with the exterior; the single eye disappears; the body becomes deformed and is invested by a thickened cuticular test, which contains **cellulose.** The ventral heart is simple and tubular, and there is a periodic reversal in the direction of the blood current. There are no kidneys in the strict sense, and no renal ducts. All are hermaphrodite. There is usually a **metamorphosis** in the life-history and sometimes **alternation of generations.** Colonies are frequently formed—for the last time in the scale of classification.

A TYPICAL ASCIDIAN.—A common shape of an adult Tunicate, like *Ascidia*, is like a double-mouthed leather bottle. At the uppermost end there is an inhalant aperture or mouth; somewhat to the side is an exhalant aperture; and when the creature is touched it can send out a jet of water from either opening—whence the colloquial name ' sea-squirt.' The name Tunicate refers to the clear ' tunic ' or ' test ' which envelops the body, and fixes it to the rock, shell, or seaweed. It consists in part of **cellulose,** the material, allied to starch, which makes the cell-walls of plants. The tunic begins as a non-cellular cuticle, but cells migrate into it, and even blood-channels are established.

Below the ' test ' is the true skin, in which there lie numerous very distinct *unstriped* muscle-fibres, that are slowly contracting, like those on the wall of our bladder.

Between the two openings lies a single ganglion, all that is left of the central nervous system. So this defines the dorso-median line, and enables us to distinguish between the right-hand side of the animal, to which the muscle-fibres are almost restricted, and the left-hand side, which shows a twisted intestine and the reproductive organs.

The Ascidian feeds on microscopic plants and animals, which are drawn into the basketwork-like pharynx by the ceaseless wafting of the living lashes or cilia surrounding the hundreds of (secondary) gill-slits. Through these the water passes into the atrium or peri-branchial cavity which leads to the exhalant aperture. The food-particles would follow the water, but they become glued together into threads by a secretion from a ventral groove (the *endostyle*) in the pharynx, and are then swept, along a dorsal ciliated ridge, to the left side of the animal where there are a short gullet, a stomach, and an S-curved intestine which ends near the exhalant aperture. On the ventral side, at the lower end of the pharynx, lies the peculiar, reversible, single-chambered heart.

On the left side lie clear sacs, containing uric acid, which are the *analogues* of kidneys. Here also are the hermaphrodite reproductive organs, the testis surrounding the ovary and ripening at a different time (**dichogamy**), so that cross-fertilization occurs (as in most other hermaphrodites).

LIFE-HISTORY.—The eggs are probably fertilized in the exhalant chamber, but are soon liberated into the sea. Each develops into a ball of cells (the *blastula*) and a two-layered sac of cells (the *gastrula*), just as in the lancelet (q.v.). The next stage is the free-swimming larva, with a locomotor tail and the Chordate characters that we have already mentioned. It is suggestive of a miniature tadpole. After some hours of free-swimming the tadpole Ascidian fixes itself by its head and undergoes rapid degeneration. It loses its tail, its spinal cord, its eye, its notochord, and more besides; the body becomes bent upon itself and strangely deformed; the gill-slits, two pairs in the larva, become very numerous; and a tunic begins to be formed. In a few hours after it settled down, it has put on the features of an Ascidian. The development has several striking resemblances to that of the lancelet, and it is probably safe to say that both classes diverged from a common stock of Primitive Chordata.

SURVEY OF THE CLASS.

(1) **Larvacea.** A few pelagic solitary forms which show little or no degeneration, e.g. *Appendicularia, Oikopleura, Fritillaria.* They

show an interesting filtering apparatus for capturing Diatoms and Protozoa.

(2) **Ascidiacea.** Very numerous, usually fixed and degenerate Ascidians. Many are solitary, many form colonies by budding. Very typical are the genera *Ascidia, Phallusia, Ciona.* Common colonies are *Botryllus* and *Polyclinum. Pyrosoma* is aberrant in being a free-swimming colony, often as long as one's arm. It is brilliantly luminescent.

(3) **Thaliacea.** Free-swimming, transparent, pelagic forms, which may be either single or social, and exhibit alternation of generations. They are specialized rather than degenerate, but are far removed from the *Larvacea.* Two common genera are *Salpa* and *Doliolum.* The Salps are sometimes so abundant that the multitudes do much harm by breaking the fishermen's nets in which they become entangled.

Lancelets

AMPHIOXUS.—In some ways the little creature called the lancelet, whose name is certainly not a household word, is the best known of all animals. It is a translucent animal, two or three inches in length, widely distributed in shallow seas, elusive and unfamiliar, yet uncommonly well known. There are two reasons why it is much more thoroughly known than, say, a herring. In the first place, it is of fascinating interest in being a pioneer among primitive backboned animals, and therefore of compelling attractiveness to students of zoology. In the second place, its body ' cuts well ' in the microtome, and every millimetre of its length has been microscopically explored many times by the keenest eyes.

The first specimen to be described was sent from Cornwall to the German zoologist, Peter Simon Pallas, who, in 1778, made the bad mistake of regarding it as a slug. In 1834 it was rediscovered by Gabriel Costa in the Bay of Naples, and was rightly recognized as related to fishes. Costa watched living specimens and noticed their extraordinary sensitiveness to intense light, which they cannot endure. He gave them the specific name ' lubricum ' in reference to the way they slip through the fingers when touched. A couple of years later William Yarrell gave a further description in his *History of British Fishes,* and invented the technical name **Amphioxus,** which means ' sharp at both ends.' The name ' lancelet ' also refers to the characteristic pointedness. Yarrell deserves credit for recognizing the significance of a skeletal rod that runs along the lancelet's dorsal middle line, for he discerned that it corresponds in a general way to the vertebral column of obvious backboned animals. Since Yarrell's

day half a dozen distinguished zoologists, notably Johannes Müller and Sir E. Ray Lankester, have done justice to Amphioxus.

There is more than one kind of lancelet, but the eight or so species that are distinguished are very like one another; and they are all shore-dwellers, often at a depth of two fathoms. Their almost world-wide distribution, including an occasional occurrence on British coasts, may be correlated with their antiquity. They are archaic pioneers, and they have had time to colonize almost all the seas.

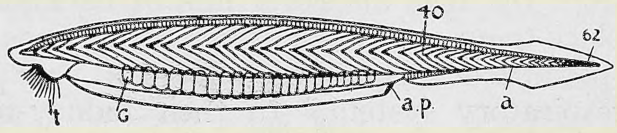


FIG. 164. THE LANCELET (*Amphioxus*) IN LATERAL VIEW

The notochord runs from tip to tip. *t*, tentacular cirri; G, reproductive organs; *ap*, atriopore; *a*, position of anus; 40, 62 indicate number of myotomes.

Lancelets are interesting in their combination of agility with easy-going ways. Professor Willey, who has written a fine book on *Amphioxus* in the Columbia University Biological Series, notes that if an individual be dropped on to a mound of wet sand, which has just been dredged, it will burrow to the lowest depths of the hillock in the twinkling of an eye. This is facilitated by the shape of the body and by the unique forward extension of the firm but elastic supporting axis. The agility which they show in retreating into the sand is also seen when they rouse themselves to swim freely. The muscular body is beautifully undulated from side to side in the water, but the effort does not last long, and the swimmers sink down on the sand. They rest for a while on their right or left side, and then bury themselves till nothing is seen save the circlet of ciliated processes (*cirri*) which waft diatoms and the like into the mouth. Thus the feeding is of a very passive type; there is no search for food, only an inwafting of minutiae. In appropriate places, such as the famous salt-pools near Messina, there may be a great crowd of lancelets living close together—an unenterprising life of ease.

Amphioxus has no eyes in the strict sense, but at regular intervals along the spinal cord there are dark pigment spots, and these seem to be affected by rapid changes in illumination, the light passing through the translucent body. Just as there are scientific instruments that register the lighting of a candle many miles away, so the lancelet's nervous system is what one may almost call **hyperaesthetic** to bright or sudden illumination. Professor Willey tells us that ' if a lighted candle be carried into a dark room in which specimens of *Amphioxus* are being kept in glass jars, the excitement produced among the small fish is indescribable.'

Willey calls lancelets ' small fish,' and deliberately, of course; but it must be realized that they occupy a position far below the level of

fishes in the ordinary sense. Thus, they have no skull, no jaws, no paired fins, no scales, no proper brain, no eyes or ears, no definite heart, and the list might be continued further. It almost looks as if lancelets consisted largely of negations, till we lay stress on *the spinal cord, the dorsal supporting axis, the gill-slits, and the muscle-blocks* (myotomes), over fifty in number. It is the possession of these fundamental Vertebrate characters that gives the lancelets their great zoological interest as survivors of archaic pioneers not far removed from the true ancestral line of backboned animals. We should not place them on the direct line itself, since they are in many ways highly specialized. Thus, they have a very remarkable and complicated respiratory system. In their kidney-tubes and in their numerous reproductive organs (sometimes twenty-six pairs) they hark back to sea-worms; and it is a rather quaint fact that they are often accompanied by worms called *Ophelia*, which resemble lancelets not only in shape and size, but also in their ways of burrowing and swimming. Speaking of relationships, we must not omit to notice that in some features, such as the numerous gill-slits and the structure of the pharynx, lancelets show an indubitable resemblance to sea-squirts or Tunicates, which they are otherwise as unlike as possible.

Lancelets have not many 'habits,' but they are profoundly interesting to evolutionists. They throw light on origins. Also to the embryologist they have proved illuminating. Thus Professor E. B. Wilson has shown that if one shakes the water in which the two-cell stages of development are floating, the result may be two separate twins of half the normal size. In other words, each half develops as if it were a whole. But if the shaking separates the two first cells in an incomplete way, the results are short-lived double embryos, united like Siamese twins. Similarly when the fertilized egg-cell has divided into four cells, vigorous shaking of the water may result in four dwarf embryos from each egg. Less vigorous shaking and incomplete separation may lead to the development of quaint united quadruplets, which do not, however, possess much viability. When the eight-cell stages are shaken to pieces the development of each fragment does not go far. This may be interpreted as due to the fact that division of labour has begun to set in. The individual segmentation-cells are losing the all-round completeness which is possessed by those of the two-cell and four-cell stages. There are many other illuminating tricks that may be played with lancelets' eggs.

A Round-mouth or Cyclostome: The Glutinous Hag

MYXINE.—This is not the story of a nightmare; it is an appreciation of one of the most interesting animals in our seas. It might sound

more polite to speak of the 'glutinous hagfish,' but it would be less accurate, for we cannot agree with those authorities, like Dr. Harry M. Kyle, who insist on regarding *Myxine glutinosa* as a kind of fish. It is indeed rather suggestive of an anaemic eel, but how dare we apply the word fish to a creature *without distinct jaws, without paired fins, and without any hint of scales*? Moreover, it has an unpaired nostril which opens posteriorly into the mouth, whereas true fishes have paired nostrils without any posterior opening. It has seven pairs of peculiar gill-pockets, very unlike the ordinary gills of fishes; and its gristly skeleton is of the most primitive type.

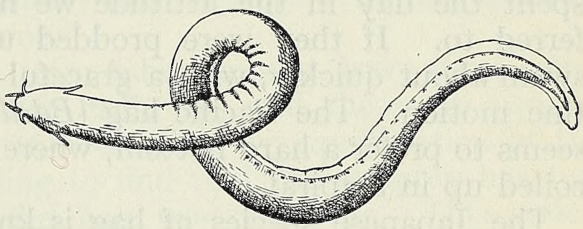


FIG. 165. THE GLUTINOUS HAG
(*Myxine glutinosa*)

To the naturalist no animal is common or unclean, even when man has vulgarized it, but there are probably few who are in any danger of being carried off their feet in enthusiasm for the glutinous hag! Yet it is far more interesting than many another animal that is superficially more attractive. It is an antique in the first place, belonging to a class of **Cyclostomes** or Round-mouths, also including lampreys, lower in the scale than Fishes. It has a very primitive cartilaginous skull and a still poorer brain. It has no backbone, only an unsegmented gristly rod, the **notochord**, which is present for a short time as a transitory skeletal axis in the embryos of higher Vertebrates. Except in some old-fashioned fishes, the notochord is almost wholly replaced by the quite distinct backbone; but the Round-mouths retain it in its entirety, and never acquire its substitute. This is a very primitive feature, and we can have little hesitation in saying that the hags and lampreys are very primitive Vertebrates which diverged some hundreds of millions of years ago on a not very successful line of their own. Some authorities link them back to a dainty little fossil called *Palaeospondylus*, found in the Lower Old Red Sandstones of Caithness, but this is a much-disputed question.

The hag is a pinkish cylindrical creature not uncommon in the North Sea, and sometimes found inside cod or haddock that have been caught on the fishermen's deep lines. A common size is sixteen inches, but we have handled big fellows nearly two feet long. They squirm vigorously, and they are difficult to hold because of the slime which is exuded from a row of large glands along each side of the body. If two or three hags are put into a pail of water and exercised a little, they surround themselves with vague sheaths of mucus-threads, so that one finds it difficult to close one's fingers on them. This slipperiness is

probably protective against certain enemies. Hags have been dredged from the mud at a depth of forty fathoms off St. Abbs Head (Scotland) and in similar places, and the probability is that they spend much of their time resting with the tip of their snouts protruding from their soft bed. Many years ago Dr. J. T. Cunningham kept a considerable number in tanks at the Granton Marine Station, in the hope of getting them to breed, and these specimens usually spent the day in the attitude we have referred to. If they were prodded up they swam about quickly, with a graceful serpentine motion. The Pacific hag (*Bdellostoma*) seems to prefer a hard bottom, where it rests coiled up in a spiral.

The Japanese species of hag is known to make its way into floating cages containing living fishes and squids, which it attacks, but the European form is rarely found except inside fishes which have been already caught on the lines. To get inside a victim the hag uses a paired tooth-plate which can be protruded from the floor of the mouth. Each half of the plate bears two rows of sharp, horny teeth, arranged like a comb, and it is with this powerful rasp, worked by five muscles, that the hag bores into a fish and proceeds to tear off pieces of tissue. We have seen three hags inside one hooked fish, but it seems a misuse of words to call *Myxine* a parasite; it is a predatory animal devouring its booty from within instead of from without. In places where hags are abundant, as in Monterey Bay, 128 miles south of San Francisco, the fishing may be vexatiously damaged. Dr. Howard Ayers reports that he has seen large halibut 'beautifully deprived of all contents save the skeleton, and with but a single opening in the region of the gills to show where the devastator had entered the body.' This refers to the Pacific hag, called *Bdellostoma*, which varies from fifteen to twenty-five inches in length, and is interesting in having six to fourteen pairs of

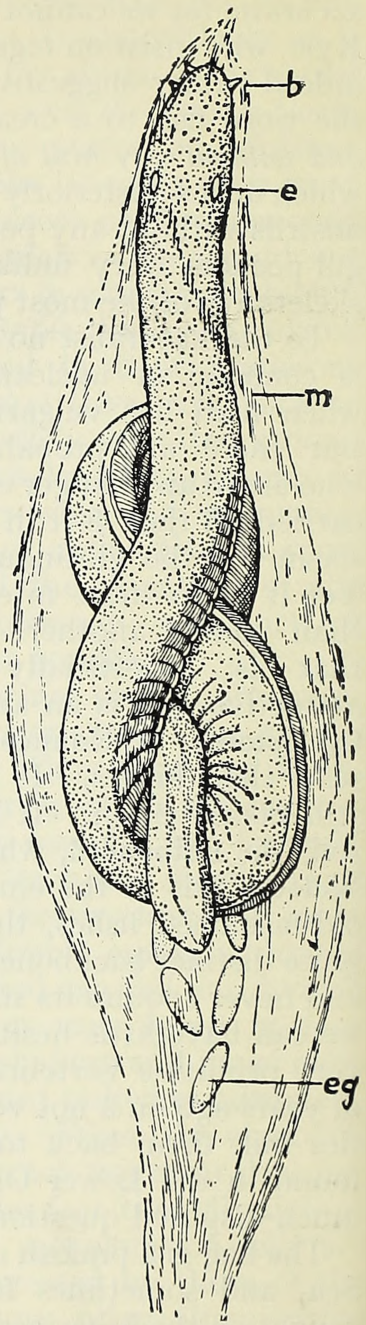


FIG. 166. THE PACIFIC HAG (*Bdellostoma stouti*).—After Bashford Dean

b, barbules; *e*, eyes; *m*, sheath of mucus; *eg*, eggs.

gill-pouches, all opening separately, whereas our Myxine has only six pairs whose efferent ducts combine in a single aperture on each side. On a living Myxine with its mouth shut, the water enters by the single nasal aperture and passes out at the two exhalant apertures, several inches along the body. Returning for a moment to the Monterey hag, we can understand the exasperation of the fishermen when they find their catches spoiled by useless hags or their sardine-baited hooks bearing only what they do not want. Howard Ayers reported in 1894 that the lines are often brought up with as many Bdellostomas as fishes. 'My Chinaman assured me that sometimes nearly all of the hooks were taken by this hagfish; or, as he expressed it: "Every hook—one sliklostome."'

Ordinary backboned animals, from fishes to man, have three semicircular canals in connection with each ear, and these are usually regarded as having to do with the balancing or equilibration of the body. Now, it is very interesting to find that the lamprey has two semicircular canals, and that the hag has only one. This series, 1, 2, 3, should be pondered over by anti-evolutionists. Living in relatively dark water, the hag has not much use for eyes, and they have remained in a state of arrested development. The eyes of Vertebrates always develop as outgrowths from the brain; those of the hag never reach the surface. As regards its eyes, the hag has failed to grow up; and this is perhaps the fundamental reason for its lying low. Dr. Kyle makes the interesting suggestion that the hag handicapped itself by its mode of development, for the way in which the embryo is pressed in tightly between the yolk and the egg-capsule involves a feeble development of the brain. But this suggestion requires a good deal of thinking over, and so does the striking fact that the hag is first a male and then a female, which is surely getting a good deal out of life! But there are some authorities who do not admit this change of sex in the individual; we can only say that in our examination of over a hundred specimens exceeding a foot in length we found them all to be females.

Another Cyclostome Type: The Lamprey

More familiar than the hags (*Myxine* and others) are the lampreys (*Petromyzon*), which are also Cyclostomes or Round-mouths. That is to say, they differ from true fishes in being jawless, limbless, and scaleless, in having peculiar gill-pockets and an unpaired nostril, and in some other features, chiefly negative. The absence of distinct jaws is an important anatomical distinction, hence the term *Cyclostome* (*cyclos*, circle; *stoma*, mouth) in contrast to *Gnathostome* (*gnathos*, jaw; *stoma*, mouth), which applies to all other Vertebrates, from Fishes to Man.

The yard-long marine lamprey of British seas is referred to the genus *Petromyzon* (*petros*, stone; *myzon*, sucker), a title that is echoed in the popular name ' stone-grig,' and refers to their habit of attaching themselves to stones by means of their suctorial mouth, or of dragging stones together to make a sort of nest. There are two other British species—the river lamprey or lampern (*Lampetra fluviatilis*), nearly two feet, often in the sea; and the brook lampern (*Lampetra planeri*), usually under twelve inches long. They depend mainly on fishes, but also eat worms, small crustaceans, insect larvae, dead animals, etc.; they sometimes attach themselves to living fishes, scrape holes in the skin with their ' rasper,' and suck in blood and loosened flesh.

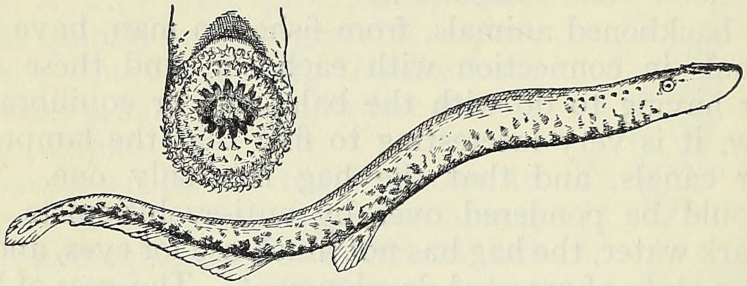


FIG. 167. THE MARINE LAMPREY (*Petromyzon marinus*) WITH AN ENLARGEMENT OF THE MOUTH

PECULIARITIES OF STRUCTURE.—We occasionally find a big lamprey lying dead by the side of the river where it has spawned; and if we do, it is an opportunity for study not to be missed, though the small ones serve not so badly. We notice the suctorial mouth, the absence of paired fins and scales, the slimy pigmented skin, the seven gill-slits on each side in front, the unpaired nostril far back on the top of the head.

The skeleton is entirely cartilaginous. The notochord persists as an unsegmented rod. The brain is relatively simple. There is no sympathetic nervous system; and the dorsal and ventral roots of the spinal nerves (q.v.) do not unite. The body is very muscular; the swimming graceful.

On the funnel-like mouth there are numerous horny ' teeth,' and others on a muscular piston (or ' tongue ') which is used in rasping. A respiratory tube below the gullet leads water from the mouth to the seven pairs of gill-pockets which open to the exterior, but some water enters, as well as leaves, by these very distinct apertures.

The gonads are unpaired and without ducts. The sexes are separate. The eggs of the female, or the sperms of the male, as the case may be, are shed into the body-cavity, and pass through two pores into the united ends of the kidney-ducts or ureters (**urinogenital sinus**), and thence out through an integumentary common chamber or **cloaca**,

into which the intestine also opens. There are many more males than females. In all species the spawning seems to be exhausting, for it is often followed by death. In an American species, *Lampetra wilderi*, the acquisition of adult characters is so rapidly followed by spawning and by death that the adults can hardly be said to take any food at all —thus reminding us of many insects.

LIFE-HISTORY. — The fertilized ovum undergoes total, slightly unequal, segmentation, and gives rise to a ball of cells (the blastula), and then to a two-layered sac of cells (the gastrula). From this there develops a **larva**, that is to say, a young stage which differs markedly from the fully formed creature. It is called a '**niner**' (nine-eyes), although its eyes have not reached the surface, the number nine being reached (in popular Natural History) by counting the seven or eight incipient gill-pouches and the place where the eye is going to emerge! The technical name of the larva is **Ammocoetes**, which was given to it under the impression that it was a separate kind of animal. More than two hundred years ago, a Strasbourg fisherman called Baldner convinced himself that 'niners' were young lampreys; but he did not convince naturalists, and it was not till August Müller studied the life-history in 1856 that the relationship was established.

The larval lamprey ('pride' or 'sandpiper') has some interesting resemblances to the lancelet, e.g. in the use of cilia to waft minute food-organisms into the mouth. Some of the cilia are outside the mouth, but most are inside the beginning of the food-canal. The glandular skin secretes a slime which includes a digestive (peptic) ferment, believed to be of use in digesting bacteria and other micro-organisms that might settle on the surface of an easy-going animal, wallowing sluggishly in the mud. As the adults spawn and the larvae develop in *fresh water*, the probability is that the exploiting of the sea on the part of certain species is a secondary adventure.

Among the differences between 'niner' and lamprey we may notice the following—the larval mouth is more horseshoe-like than circular, the larva has no teeth or exposed eyes, the respiratory arrangements are different.

The larva remains a larva for three to five years, and the actual change or metamorphosis to the adult state takes several months.

The larger lampreys are often eaten, and Henry I of England, the king 'who never smiled again,' is said to have died from a surfeit of them. On the Continent the cured and dried *Petromyzon marinus* is often seen in the shops, and with hunger as sauce makes a palatable dish. Smaller forms are often used as bait for the fishermen's long lines—for catching cod and turbot.

Careless observers often mix up 'niners' with young eels, with which, of course, they have no connection.

CLASSIFICATION.

Class **Cyclostomes** (i.e. Round-mouths) or **Marsipobranchs** (i.e. with gill-pouches).

ORDER I. *Myxinoids*, or Hags, e.g. British *Myxine*, Californian *Bdellostoma*.

ORDER II. *Petromyzonts*, or Lampreys, e.g. European and American *Petromyzon* and *Lampetra*, American *Ichthyomyzon*, Australian and Chilian *Geotria*.

OSTRACODERMS OR HYPOSTOMES

Extinct forms, known as Silurian and Devonian fossils, *the oldest known Vertebrates*, seem to be mostly related to lampreys, as in the case of *Cephalaspis*, *Pteraspis*, and *Anaspis*. They are usually marked by a prominent head-shield (*aspis*), and by the absence of distinct jaws and limbs. The associated *Pterichthys* has been shown to be nearer the *Selachians* or shark-like fishes.

CHAPTER XVII

FISHES

The first successful Backboned Animals—How Fishes swim—Shapes of Fishes—Skin and scales—Colours—Feeding habits—Multiplication—Life-histories—Parental care—Fishes in the struggle for existence—Interrelations—Classification of Fishes—Some representative Fishes—Mentality in Fishes—The Silveriness of Fishes—A Fish that puffs out light.

THE FIRST SUCCESSFUL BACKBONED ANIMALS.—There may have been shoals of primitive backboned animals living in the sea many millions of years ago, but they have not left more than a few traces in the fossil-bearing rocks. Fish remains are reported from Cambrian strata, which must have been laid down at least 400 million years ago. But the ancestors of these Cambrian fishes are unknown. They probably had small beginnings, but they gradually became a prominent feature of life in the sea, and there are many fossils of more or less fish-like forms in the Silurian, and of very definite fishes in the Devonian. But our point is simply this, that the old-fashioned backboned animals or Chordates of to-day, those that are below the level of fishes, namely Ascidians, Lancelets, and Round-mouths, have not been much of a success. Most of the Ascidians are degenerate; the Lancelets are pygmies, few and far between; the Round-mouths or Cyclostomes are represented only by lampreys and hags. Thus *fishes are the first successful backboned animals.* They show their success in the large number of different kinds, in the number of individuals in many of the shoals (e.g. herring), in the way in which they have peopled almost every corner of the sea and of the fresh waters, in their mastery of their medium, and in the way they hold their own in spite of many enemies. Fishes have a freedom in the water that resembles the freedom of birds in the air.

HOW FISHES SWIM.—The great majority of fishes swim by their muscular posterior body (more than we can well call ' tail '), which they use to displace masses of water first to one side and then to the other. Except in a few cases, like the sea-horse, the backbone of fishes moves only from side to side, not from above downwards (as a beaver's does); and while the tail region of the fish may be thought of as a propeller, it is a propeller that does not go round. Muscular contractions take place alternately on the two sides of the body.

In the members of the skate tribe, where the tail has become a

weapon (as in the sting-ray), the swimming is effected by the broad fore-fins (or pectoral fins) which have been flattened out dorsiventrally. Waves of muscular contraction pass along them, and the water is displaced from in front backwards in a very beautiful way. Likewise in some delicate fishes like sticklebacks, the pectoral fins may be used in gentle swimming, but even here the posterior body is, as in all ordinary fishes, the propelling shaft that drives the head end forwards. What then is the main use of the paired fins, pectoral and pelvic, if they are not swimming structures? The answer must be that they help in balancing the body in the water. Fishes swim at all sorts of rates, but it may be noted that not only the huge shark, but the little bonito, can keep up with a ship doing sixteen to twenty knots—may we say nautical 'miles' an hour?

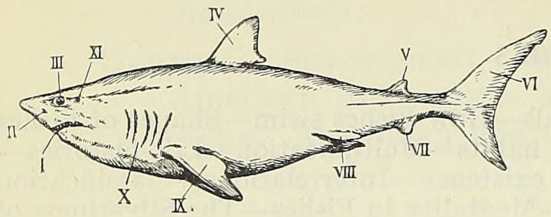


FIG. 168. EXTERNAL FEATURES OF SHARK (*Selache?*)

I, mouth; II, nostril; III, eye; IV and V, dorsal fins; VI, tail fin; VII, anal fin; VIII, pelvic fin; IX, pectoral fin; X, gill-clefts; XI, spiracle.

SHAPES OF FISHES.—Most fishes have torpedo-shaped or wedge-like bodies, well suited for rapid movement through the water. The vertical section is more or less of an ellipse. The stream-lines are like those of a yacht, and the typical shape of a fish may be called an **adaptation** or fitness—a particular adjustment of structure that makes for efficiency. From the typical shape, which we call torpedo-like, many others have been evolved. Thus the *cylindrical* shape seen in eels is well suited for creeping through narrow passages or crawling in the mud. The *globular* inflatable body of globe-fishes is well suited for floating lazily on the surface of a summer sea. The *depressed* shape of a skate is adapted for resting or swimming on the sea-floor, and that is also the habit of the bony flat-fishes like plaice and flounder. But their *compressed* body has become flattened laterally, whereas that of skates has become flattened from above downwards. It may be noticed that plaice, soles, lemon-soles, dabs, flounders, witches, halibuts, and the long rough-dab swim on their *left* side, while turbot, brill, and megrims swim on their *right*. The side that is turned down is the heavier, and its skin loses all its colouring except silver.



FIG. 169. BROAD-NOSED PIPE-FISH (*Siphonostoma typhle*)

There are other shapes, of course, such as the slender needle-likeness of pipe-fishes, the long ribbon-likeness of the oar-fish, the squat broadness of the fishing frog or angler, and quaint forms like the deep-water sea-bat or the sea-horse playing and posturing among the

seaweeds. It is a useful question to ask how the shape is adapted to the habitat and habit, but the answer must not be far-fetched.

SKIN AND SCALES.—Fishes have a delicate transparent outer skin or **epidermis**, often coming away on our fingers, like wet tissue paper. It covers the scales. The familiar slipperiness is due to slime or **mucus**, secreted by numerous *goblet-cells* in the epidermis. In other words, the skin-glands are *unicellular* except in the *Dipnoi* and in some poisonous fishes. There are also sensory endings, notably those in the **lateral line** on each side of a bony fish, and the **jelly-tubes** that meander over the under-surface of a skate. These superficial sensory structures seem to be in part tactile, and in part receptive to chemical stimuli in the water. The under-skin (the **dermis** or *cutis*) is peculiar in being without any muscle-cells. These lie below the skin, usually in clearly defined blocks or segments or **myotomes.**

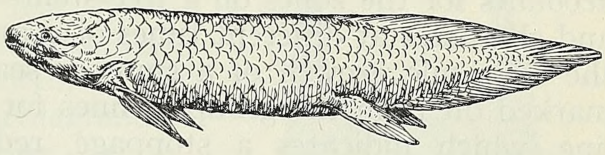


FIG. 170. QUEENSLAND MUD-FISH (*Ceratodus forsteri*), ONE OF THE *Dipnoi*

A scientific classification of fish-scales is rather intricate, and we shall not attempt it here, preferring a simpler grouping. In the sharp scale of a skate, or in the **shagreen** of a shark where thousands of minute scales or 'dermal denticles' cover the skin, there are three hard tissues. The scale includes: (1) a base of *bone* embedded in the dermis; (2) a core of ivory or *dentine*; and (3) a tip of *enamel*, which is the hardest of all tissues, and is familiar to us on the surface of our teeth. In the development of the skate's or shark's scale, the tip of enamel is formed from the epidermis, which it pierces; the ivory and bone are formed from the dermis. Whereas the scales of a reptile are wholly epidermic, though fed from the dermis, the bulk or the whole of the scale in fishes is dermic.

Now if we suppose the skate's scale reduced to its base of bone, we should have a bony scale such as we see in sturgeons. If this bony plate were varnished, so to speak, with a glistening silvery substance called **ganoin**, we should have the ganoid scale of the bony pike or gar (*Lepidosteus*).

But if instead of a hard bony plate and nothing else there were formed a flexible, almost translucent scale of a substance called *vitrodentine*, we should have the scale that occurs in the majority of bony fishes or *Teleosts*; this is known as a 'soft scale.' In cases like the herring it is so lightly built that it may be blown about by the wind around the curing stations.

When a scale is dislodged by a natural wound it is not regrown, and the number of scales at certain parts of the body is often used as a specific character, distinguishing allied species. After the fish puts on

adult characters there is no increase in the number of scales, but the individual scales may increase in size. On a typical fish-scale (e.g. of salmon, cod, herring) examined under the microscope, one sees numerous concentric lines, groups of which indicate the annual contributions made to the size of the scale as long as the fish goes on growing. Thus the age of the fish can be estimated from its scales, as also from the lines on some of the bones and from the internal zones seen inside a sliced ear-stone or **otolith.** The reason for the distinctness of the concentric lines on a scale like the salmon's is similar to that which accounts for the zones on a tree-stem—the growth is different in rate and character at different times of year. The various lines indicating the rhythmic growth of a summer season, with abundant food, are marked off from the group of lines for the next summer by a winter line, which indicates a stoppage, reduction, or marked change of growth. In some cases, as in the salmon, the changes of habitat, and such events as spawning, are clearly registered in the structure of the scale. Scales are absent in electric fishes, but not in eels as is often supposed. In sharks and their relatives the scales and the teeth show the same general structure and development, and are therefore *homologous*.

COLOURS.—It has been shown by experiment that some fishes are sensitive to outside colour, and that some, like the flat bony fishes, can rapidly change their own colour in correspondence, within limits, to that of the surroundings. This is due to the contraction and expansion of branched pigment-cells (**chromatophores**), above or below the scales, or in both places, and the expansion of the cell is influenced by a hormone from the pituitary body of the fish. This particular hormone seems to persist as a vestigial product in mammals, where the responsive tissue has long since disappeared.

FEEDING HABITS.—Some fishes, such as mackerel, feed daintily on microscopic organisms, such as the crustaceans miscalled water-fleas, while others, like the sharks, are voracious carnivores at a high level. Many of the dainty feeders depend in the main on diatoms (unicellular plants), but there are other fishes that browse on seaweeds and water-weeds. The quest for food may be by sight, by chemical sense, by smell, or by touch; but sight probably counts for most in the great majority. Many show a reflex gulping when anything even suggestive of booty comes near, and this may account for the occasional swallowing of the young, of inappropriate bait, and of food inconveniently large.

MULTIPLICATION.—Most fishes are very prolific, which may be associated with a relatively low 'individuation' or standard of structure, and also with abundant food, easily obtained. But from a different point of view, it may be said that the prolific multiplication

is adaptive to the hazardous life. In other words, those types have survived which have varied in the direction of great reproductivity. A female ling six feet long may have in its ovaries over twenty-eight million eggs, a turbot of seventeen pounds nine million, a cod of twenty-one and a half pounds over six million. The abundant herring has relatively few, twenty-one to forty-seven thousand. But even in this case it is plain that the sea would soon become solid with fish if there were not high mortality, especially in youth.

Economized reproduction has been established in various circumstances, e.g. (1) when there is viviparous birth, as in many sharks and other cartilaginous fishes; (2) when there is nesting, as in sticklebacks; and (3) when there is much parental care, as in sea-horses. Relatively heavy eggs that sink to the bottom and develop there are called *demersal*, as in cat-fish, salmon, and herring. Relatively light and buoyant eggs float at or near the surface (*pelagic*), as in almost all bony food-fishes, like cod and plaice. Pelagic eggs, which are confined to marine fishes, are usually transparent, and their buoyancy is increased by a large oil-globule which is uppermost when the eggs are floating in the water. Except in viviparous forms and a few others, fertilization is external and with much wastage. In most cases the segmentation of the egg is partial and discoidal.

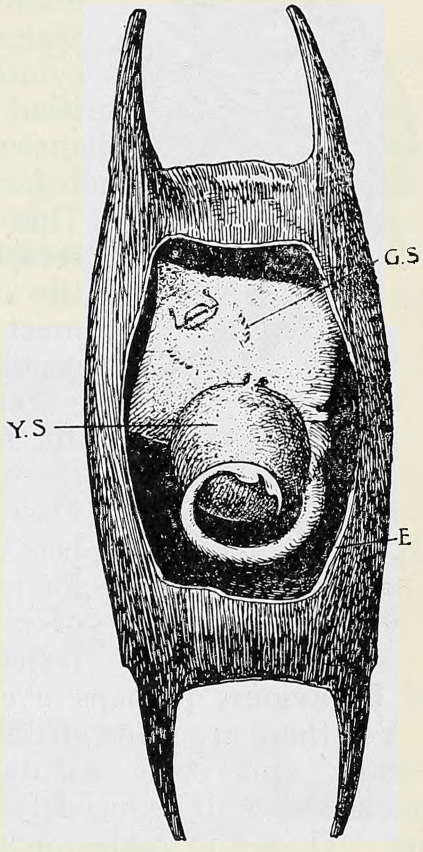


FIG. 171. EMBRYO SKATE IN MERMAID'S PURSE

E, cut edge of purse; GS, gill-slits; YS, yolk-sac.

LIFE-HISTORIES.—What comes out of one end of the skate's horny egg-case (the '*mermaid's purse*') is a fully formed little skate, which has passed through a long **direct development.** In other words, there is not in the skate any larval stage, and the same may be said of dogfishes and sharks. But in the great majority of fishes, what comes out of the egg is in several important respects unlike the parent. In other words, most fishes have **larvae,** which undergo some degree of metamorphosis before they assume the adult characters. The development is **indirect,** but there are degrees of indirectness. In some cases the features of the newly hatched creature are only slightly different from those of the parent; in other cases the differences are

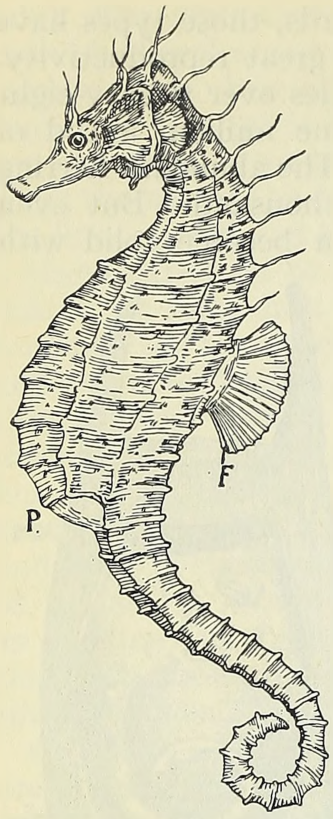


FIG. 172. MALE SEA-HORSE (*Hippocampus*)
P, brood-pouch; F, dorsal fin.

very marked. Thus the larvae that develop from pelagic eggs are usually mouthless to begin with, with colourless blood, with a continuous dorsal fin, and may be for a while without gill-clefts. Many instances of remarkable larvae are known, such as those of the angler and the eel, to which we have referred elsewhere. The larvae of flat-fishes of the plaice and sole type are at first bilaterally symmetrical, with an eye on each side of the head and an unflattened body; they pass through a long and drastic metamorphosis before they put on the familiar adult features. This is a good instance of the individual's **recapitulation** of the evolution of the race, for the ancestors of bony flat-fishes (*Pleuronectids*) must be looked for among symmetrical forms, usually described as 'round.'

PARENTAL CARE.—When thousands of eggs are liberated at one time, as in most fishes, there is not likely to be any parental care. First, because it is not needed, the huge numbers allowing sufficient margin in the struggle for existence; secondly, because the conditions of prolific multiplication are not such as to foster variations in the direction of the kind of behaviour, perhaps even emotions, that parental care implies.

Yet there are some striking instances of parental—usually paternal—care, and it is naturally associated with reduced families. Thus the male stickleback makes a nest of freshwater weed or of seaweed, according to the species, the pieces being bound together by means of glutinous threads secreted from the male kidneys at the breeding season. About a score of fishes are known to make nests.

The male sea-horse (*Hippocampus*) carries in a ventral pouch the eggs which the female has liberated. In the

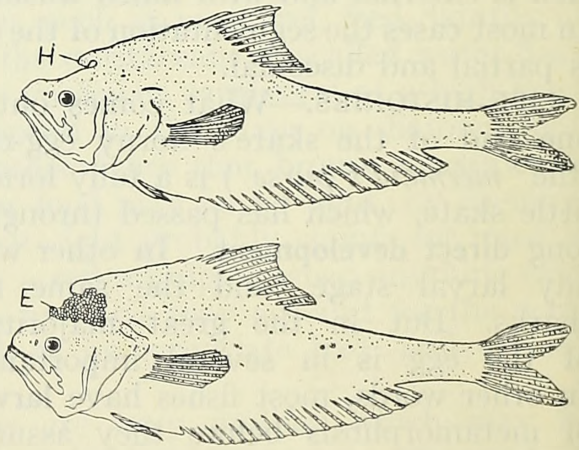


FIG. 173. MALE OF KURTUS, carrying eggs
The upper figure shows the bony hook, H, the lower figure shows the bunch of eggs.

pipe-fishes (*Syngnathus*) the shelter is a ventral groove on the male. In *Arius* the male shelters the eggs in his pharynx. In a freshwater New Guinea fish (*Kurtus gulliveri*), the male carries a double bunch of about a hundred eggs on the top of his head, attached by a bony process that develops at the breeding season, first forming a hook and then an eye.

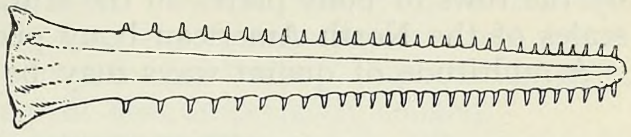


Fig. 174. Saw of Saw-fish (*Pritis antiquorum*)

Sometimes the female takes charge, but less frequently. Thus the female *Aspredo* carries the eggs on her ventral surface until they are hatched. In some female Cichlids the female not only keeps the eggs in her mouth while they are developing, but allows the hatched young ones to come and go, which seems like ' tempting providence.'

FISHES IN THE STRUGGLE FOR EXISTENCE.—Sharks stand for voracity, and some of them will attack whales. There are many

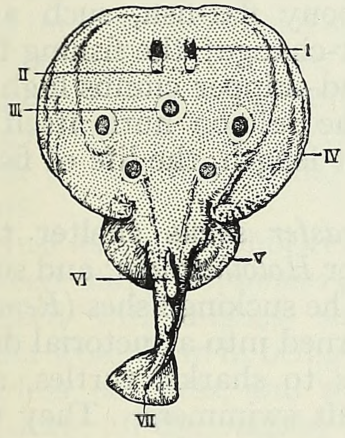


Fig. 175. The Electric Ray (*Torpedo ocellata*)

I, eye; II, spiracle; III, electric organs; IV, pectoral fins; V, pelvic fins; VI, dorsal fin; VII, caudal fin.

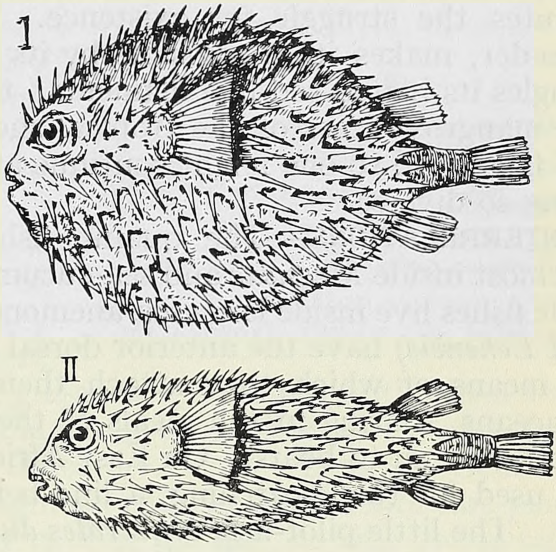


Fig. 176. The Porcupine Globe-fish (*Diodon*)

I, inflated; II, deflated.

notable fish-weapons, such as the toothed beak of the saw-fish (*Pritis antiquorum*), which may project for six feet beyond the skull. Very striking are the **electric organs,** best developed in *Torpedo,* in the South American electric eel (*Gymnotus*), and in the African siluroid (*Malapterurus*), all of which can give a considerable shock. In the three cases mentioned the structure differs, but the essential part of the electric organ always consists of strangely modified muscle substance and very elaborate nerve-endings. It should be noted that

every muscular contraction, in ourselves for instance, has an electric change associated with it, but in these electric fishes what is inappreciable elsewhere has become greatly exaggerated.

Armour is well illustrated by the box-fishes and globe-fishes, as also by the rows of bony plates on the sturgeon and the beautiful ganoin scales of the North American bony pike.

A multitude of quaint ways may be thought of in illustration of

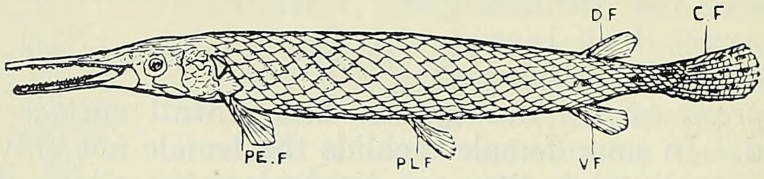


FIG. 177. THE BONY PIKE (*Lepidosteus osseus*)
PE.F, pectoral fin; PL.F, pelvic fin; VF, ventral fin (unpaired); DF, dorsal fin; CF, caudal fin. Note the rhomboidal 'ganoid scales.'

that endless endeavour to face difficulties and limitations which constitutes the struggle for existence. The bony flat-fish, such as a flounder, makes itself invisible by its colour-change; the fishing frog dangles its baited rod-like filaments; the mud-skipper climbs high on the mangrove trees of the tropical shore; the salmon hurls itself up the falls; and so one might continue at great length, the life of fishes being so diverse.

INTERRELATIONS.—The quaint fish *Fierasfer* seeks shelter tail-foremost inside *Medusae* and sea-cucumbers or *Holothurians*; and some little fishes live inside large sea-anemones. The sucking fishes (*Remora* and *Echeneis*) have the anterior dorsal fin turned into a suctorial disk, by means of which they attach themselves to sharks, turtles, and cetaceans, sharing in the meals of these swift swimmers. They will also fasten on to boats. On East African and some other coasts they are used for turtle-catching, a line being fastened to the root of the tail. The little pilot-fish, *Naucrates ductor*, of the Open Sea, a relative of the horse-mackerel, has become a companion of sharks, perhaps gaining crumbs from the meals and perhaps some protection from the alliance, while the predatory partner has perhaps the advantage of some guidance from quicker senses. But there is much 'perhaps' about this!

Fishes contain many parasites, but are nevertheless very healthy animals in most cases. Salmon disease is due to a bacterium (*Bacillus salmonis pestis*), followed by a fungus (*Saprolegnia ferox*) with external white patches, and may be in part due to depressed vitality brought on by contaminated rivers. Apart from Protozoa, the commonest parasites of fishes are: (1) fish-lice (really crustaceans), which hang about the skin and gills; (2) flukes or *Trematodes*, especially in the gill region; (3) tapeworms or *Cestodes* in the intestine, with their bladder-

worm stages in various parts of other fishes on which the host of the tapeworm normally feeds; and (4) numerous threadworms, especially in the food-canal and about the viscera. As man often depends to no small extent on fishes, it is important to note that relatively few of the parasites are in the muscles or flesh. In the case of the formidable tapeworm called *Bothriocephalus latus*, the young stages live in a water-flea (*Cyclops*), the later stages in pike and burbot, the adult in man, who becomes infected by eating the flesh imperfectly cooked.

Interrelations connected with reproduction may be illustrated by the bitterling (*Rhodeus amarus*), which inserts its eggs, by means of a long ovipositor, in the gill-plate of a freshwater mussel, such as *Unio* or *Anodon*. On the other hand, the larvae (*glochidia*) of freshwater mussels require to spend their later larval stages in the skin of the tail, fins, or gills of a freshwater fish, such as minnow, stickleback, trout, or alligator-gar (*Lepidosteus*). (See FRESHWATER MUSSEL.)

CLASSIFICATION OF FISHES.—This is a difficult problem, for even among the living or extant species (over 20,000) there is great diversity, and the fossil or extinct species show many different levels of structure. Perhaps there is more diversity among Fishes than among any other great group of Vertebrates, such as Reptiles, Birds, or Mammals.

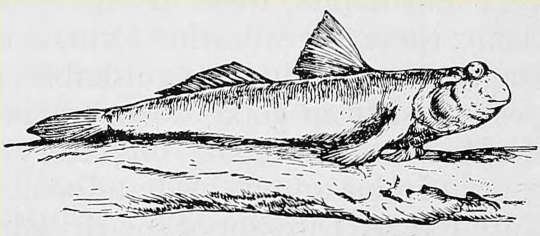


FIG. 178. THE MUD-SKIPPER (*Periophthalmus*), ONE OF THE *Dipnoi*

Just as most authorities are now agreed that *Cyclostomes* cannot be ranked with Fishes, since they differ from them in being limbless, jawless, scaleless, and without gill-arches, so many authorities would separate off the *Selachii* or cartilaginous fishes (like sharks and skates) as a separate class from true fishes or *Pisces*. Thus the Selachians are marked by having a cartilaginous endoskeleton, tooth-like placoid scales, thorny as well as gristly rays in the fins, no ribs bounding the abdominal cavity, and no air-bladder. They include: (*a*) the shark-like forms; (*b*) the flattened skate-like forms; and (*c*) the *Chimaeras* or *Holocephali*, which stand rather by themselves.

If we leave the gristly fishes by themselves, and rank all the others in a separate class of Pisces, they may be divided into three sub-classes:

First. The '**ancient-finned**' (**Palaeopterygii**), such as sturgeons (*Acipenser*), bichirs (*Polypterus*), spoonbills (*Polyodon*).

Second. The '**new-finned**' (**Neopterygii**), such as the old-fashioned gar-pikes (*Lepidosteus*) and bow-fin (*Amia*), and thousands of bony fishes or *Teleostei*.

Third. The '**fringe-finned**' (**Crossopterygii**), including the three living mud-fishes, lung-fishes, or *Dipnoi*, and many fossil forms.

Some Representative Fishes

SEA-TROUT.—The angler is not usually impressed by the zoologist's declaration that there is only one species of trout in Britain, namely *Salmo trutta*. What, he says, of the brook-trout, and the 'ferox' of the lakes; what of the phinock in the east and the sewen in the west; what of the trout of Loch Leven and the Irish gillaroo? What especially of the silvery sea-trout which migrates to salt water; how can it be the same species as the non-migratory brown trout of rivers and lakes?

The biologist would reply to the question whether there is or is not more than one species of trout in Britain, that if we make different species of river-trout and sea-trout we should have to do the same, or much more, for fantail and pouter pigeons, for cabbage and cauliflower, and for other instances of domesticated animals and cultivated plants where there are many varieties all descended from one wild species, such as the rock-dove and the sea-kale in the cases just mentioned. The fact is that though typical sea-trout differ from typical river-trout in appearance and habits, there are no constant structural differences between them; there are estuarine forms intermediate in appearance; the young stages are quite indistinguishable; sea-trout will breed in fresh water if prevented from going down to the sea; brook-trout imported to New Zealand have become migratory; and so the convincing argument runs. In his admirable handbook on *British Freshwater Fishes*, Dr. C. Tate Regan, Director of the British Museum (Natural History), clinches the argument by pointing out that in the Hebrides, Orkneys, and Shetlands, where there are no ordinary freshwater fishes, such as roach or pike, every river and loch is full of brown trout, 'which is only to be explained by the supposition that the latter have been derived from the sea-trout, which have lost their migratory instinct in different places and at different times.'

Though less graceful than the salmon, the sea-trout is a handsome fish, silvery in general coloration, bluish on the back, with small rounded or X-shaped dark spots on the upper half of the body. The males have stronger snout and jaws, and in large cock-fish the lower jaw tends to be bent up in a hook, though not so markedly as in the old male salmon.

In the cold months the eggs are laid and fertilized in the gravelly bed of the stream; they hatch out in spring, and the **fry** keep in hiding until able to fend for themselves. For a variable period, dependent on the food-supply in the river, the growing trout remain in a **parr** phase, the longest time recorded for the British Isles being six years. This record was for two fish from the River Ewe, that flows out of Loch Maree; and we can readily understand the lengthening out of the parr

period in the north, where the nutritive resources of the streams are poor. The staple diet consists of freshwater snails, insect larvae, small crustaceans, and worms.

In most cases the change from the parr to the **smolt** phase occurs early in the third year; and then the young fish, from four to eight inches in length, begin to migrate without any hurry to the estuary and the inshore waters. Nearly three-fourths of 1,500 sea-trout studied by Mr. G. H. Nall from 1912 to 1923 in the River Ewe and Loch Maree, undertook their smolt migration after three years of river life; but further south in Scotland the journey is begun at an earlier age. After a summer in the sea, where they feed eagerly on sprats, sand-eels, molluscs, and the like, the fish is towards a foot long, and weighs about a pound. The cold months, when there is very little feeding, may be spent in the rivers; but the first spawning is not before the winter or late autumn of the following year. Of the Ewe sea-trout that showed spawning marks on their scales, Mr. G. H. Nall found that 48·8 per cent spawned for the first time in the second winter after their smolt migration, and 40·6 per cent in the third winter.

The ranks of sea-trout are always being scrutinized by hungry eyes, and there is severe elimination from the eggs and fry onwards. Now the eliminator may be a pike and again a gull; here a codfish and there a cormorant; there is a close winnowing. There seems also to be considerable cannibalism. In spite, however, of the many **chances of death,** sea-trout hold their own well, and lucky individuals may reach a length of four feet and weigh nearly fifty pounds. This is a fine illustration of the well-known fact that many, if not most, kinds of fishes have not the definite **limit of growth** that almost all animals show. A haddock may grow to the size of an average cod, and a sea-trout may rival a salmon. The *proportions* of the body must be well adjusted, for the growth continues year after year, till at length the fish comes to an end—not from old age, but from some thrust of outrageous fortune. Most sea-trout die a violent death, and anglers will agree that they die game. In many animals, from butterflies to eels, reproduction is the beginning of death. Giving origin to new lives is often the end of the old. But it is to the credit of the sea-trout's constitution that spawning may be many times repeated. The oldest fish in the River Ewe collection had spawned eight times and was thirteen years old—a fine record.

Sea-trout do not as a rule go so far out to sea as salmon do, and they are often seen in shoals near the coast. If we hold to the conclusion that animals frequenting two quite different habitats reproduce in their *original haunt*, then sea-trout are freshwater fishes that have taken to exploring the sea, just as the common eels are deep-ocean fishes that have taken to exploring the fresh waters. When we watch an

autumn run of sea-trout up a river, we should add to the thrill of the sight the historical reflection that many at least of these handsome creatures, swimming vigorously against the stream, are returning to spawn in their own cradle-waters and in the original home of their race.

THE BUTTER-FISH.—On northerly shores with stony rock pools we are sure to find, and almost as sure not to catch, the butter-fish or gunnel. It is often about six inches long, of a mottled purplish-brown colour with dark spots here and there, and with a laterally compressed body, well adapted for wriggling through narrow passages. Even when we chivy it into a narrow corner of the shore pool it usually escapes at the last moment through an undetected hole. It has been called the ' knife-fish ' because of its power of, as it were, cutting its way into freedom. Its body suggests a knife-blade. Even if we get our hand over it, the gunnel squirms through our fingers, as slippery as an eel. It has very small scales and a thick slimy secretion. For this reason it is called butter-fish, but we must not think of it as soft; it has great muscular strength in proportion to its size. Its relationships are with the blennies, and its technical name is *Pholis* (or *Centronotus*) *gunnellus*.

It is usually about midwinter in northern Europe that the gunnel becomes ripe, and seeks out a shelter for egg-laying. There is good reason to look for a hiding-place—**the struggle for existence** is very keen on the seashore; and though the gunnel often migrates for a time into deeper water, it is distinctly a *littoral* fish of the northern coasts. Not only must the eggs be hidden, they must be placed where they cannot be washed out to sea by the ebbing tide. The need for care is accentuated by the fact that there are not many eggs altogether. There may be six hundred, but that is not many for a fish.

The gunnel's parental behaviour, for the most part at an instinctive level, is very interesting. When the eggs, each about a twelfth of an inch in diameter, are liberated from the female, they adhere together in a clump. There is an adhesive opalescent egg-envelope surrounding the egg proper, which consists for the most part of the yolk, including a relatively large oil-globule. In the vast majority of bony fishes the liberated eggs float away from one another in the sea, but there are familiar cases, like the bullheads, where the eggs have glutinous envelopes and cohere in clumps, which are attached to stones and the like. The herring differs from ordinary food-fishes in having eggs that sink to the bottom of the sea, where they become attached in masses to zoöphytes and the like. The first point, then, in regard to the gunnel's eggs is that they cohere in small clumps, each clump about the size of a walnut.

The next chapter is unusual; the parents take turns in pressing the eggs together into a neat ball. This is done by encircling them with

the sinuous body and then gently squeezing them together. Sometimes the fish uses too much pressure, as has been observed in aquaria, and the clutch of eggs slides out altogether, only to be once more encircled. The body of the fish is twisted round so that the head is resting dorsally near the tail. Part of the meaning of the compression of the egg-ball is to make it more compact and thus more readily hidden. But there is a further significance when the male compresses the clump for the first time, for there is a discharge of **milt** or seminal fluid, and the eggs are fertilized. Thus the **fertilization** is much more certain than it is in the majority of fishes, where the eggs and the sperms are simply discharged into the open sea—a wasteful method that makes the continuance of life very fortuitous. It would not be a successful method at all, if it were not that most of the fishes of the Open Sea are extraordinarily **prolific.** Thus the cod and the conger-eel are credited with eight to ten millions of eggs, and the ling may have six times as many. The record seems to be held by the sun-fish, which is said to have three hundred million eggs in its ovaries!

But when we turn to fishes that have some sort of parental care we find, instead of millions, only hundreds of eggs. In nesting fishes, like the sticklebacks, the number may be even less. In short, the evolution of parental care makes **reproductive economy** possible; or, to state the case the other way round, a marked reduction in reproductivity is not likely to be a success unless the chances of death are greatly reduced by parental care or in some other way. In all probability there were **simultaneous variations** in the two directions — economized reproductivity and increased parental care—two trends conspiring towards survival. In any case, the fact is that the gunnel, with a relatively small number of eggs, say five or six hundred, is able to secure their safety and also to ensure their fertilization. But the carefulness does not end with making a ball of the eggs and coiling round them.

In the simplest cases the gunnel huddles under a loose stone and remains there guarding the ball of eggs. Both parents may be present, sometimes coiled in opposite directions round the precious clutch; or one may be embracing the eggs closely, while the other is near at hand; or there may be only one fish in attendance, either male or female. Aquarium observations show considerable variability, but there is general agreement that both sexes share in the parental care, and that there is not much evidence of meals. It may be, however, that the sexes relieve one another in natural conditions, and that the tide brings in little fragments of food. Mr. E. W. Gudger, of the American Museum of Natural History, who has made a careful study of the gunnel, notes that partial starvation is exhibited by the male toad-fish (*Opsanus tau*), which lays its adhesive eggs in the hollow of an empty *Pinna* shell and mounts guard over them. It is also seen in the marine

catfish (*Felichthys felis*), the male carrying the developing eggs in his mouth for eighty days, and having perforce to fast all the time. The inhibition of the natural swallowing reflex is of much interest, but we dare not use any big psychological word like ' resolution ' !

The gunnel attains greatest safety for its ball of eggs when it gets them into a hole bored by the piddock or *Pholas* in a soft rock. In such cases the probability is that the female fish first gets into the hole and then liberates the eggs; sometimes both parents are found along with the eggs in the one hole. Another very effective shelter, which has been often observed, is afforded by an empty oyster shell. The gunnel lies with its egg-ball in the hollow of the left valve, that is the valve which, in the ordinary circumstances of the living oyster, is turned downwards and fixed to the substratum. The normally upturned *flatter* valve of the oyster corresponds to that of the right-hand side in ordinary bivalve molluscs. As in other cases, both parents have been found in association with the oyster shell, one inside, and the other just outside.

The development of the gunnel's eggs is relatively slow in the cold water, and March is a common time for the hatching. The newly hatched **larvae** are only about a third of an inch in length (about an inch by midsummer), but in a short time they swim away and the parental task is over. As gunnels are very common, we must credit the young ones with being well equipped to meet their chances of death.

OTHER SHORE-FISHES.—In the seashore pools we find, besides the gunnel, a number of characteristic fishes which are well adapted to that particular habitat. Among these we may give a prominent place to the elusive **sand-eels** (*Ammodytes*), greenish and silvery, but, instead of living among stones, they burrow with the help of their protruding lower jaw in the sand, and disappear very quickly when disturbed. They sometimes swim in shoals in shallow water over a sandy bottom, and are cleverly caught by gulls when they come too near the surface. Near a bird-berg one sometimes sees an almost continuous flight of kittiwakes and the like, each with a silvery sand-eel in its mouth—a small contribution to the nestling's appetite.

In great contrast to the elegant gunnel and sand-eel is the **lump-sucker** (*Cyclopterus lumpus*), whose plump tubercled body suggests a bloated giant tadpole with almost no tail. The male may be a foot long, and is gorgeous in crimson and orange at the breeding season; the female may be twice as large and remains soberly slate-coloured throughout the year. In early spring the female lays the heavy, bright pink eggs in the corner of a shore pool, where they adhere to stones. The male mounts guard over them, and he has been seen aërating and cleaning the bunch with very vigorous strokes of his fore-fins. In this effective paddling, to which the Scots name, ' **cock-**

paidle,' probably refers, he is helped by a ventral sucker, by which he takes a firm grip of the rock.

It is interesting to find that this characteristic sucker of the lumpsucker is simply a transformation of the hind-fins—Nature's way of making an apparently new structure out of something very old. The everyday use of the sucker is to give these quaint, feebly swimming fishes a hold on stones, so that they may not be washed ashore. In spite of this there is often great mortality during the storms of spring, when the lumpsuckers come close to the rocks. The young lumpsuckers are common among the seaweed of the shore pools, and are very engaging. They are like tadpoles, they tuck their transparent tails round their head in a very quaint fashion when they fix themselves to rock or seaweed. Their movements are lively—a promise unfulfilled—and the variable colouring of the body, combined with the transparent tail, enables the little creatures to make themselves invisible against certain backgrounds.

One of the commonest of shore-fishes is the sea-scorpion or **bullhead** (*Cottus scorpius*), first cousin of the smaller father-lasher or 'lucky-proach' (*Cottus bubalis*). Both show a very broad head, flattened above so that the eyes are on the top. The bullhead is lively and voracious, well protected by spines, especially by those on the gill-cover, which can be greatly distended when the creature is molested. The sea-scorpion does not and cannot sting, but it is able to produce a curious sound in a mechanical, non-vocal way. The male is memorable for his care of the eggs, which are usually glued into a crevice in the rock.

The three-spined **stickleback** (*Gastrosteus aculeatus*), which is at home in fresh water, is also found in shore pools; and the male at the breeding season is resplendent in orange, red, and green livery, which waxes and wanes in intensity according to the creature's moods, and especially in relation to his combats with rival suitors.

The fifteen-spined **stickleback** (*Spinachia vulgaris*), which may be over six inches in length, is more characteristic of the shore pools, and is famous for the nest of glued seaweed fronds which the male constructs. After the amber-coloured eggs have been laid in the nest by his mate, or, rather, mates, the male mounts guard for a month. He drives away intruders much larger than himself, and after the young are hatched he still tends them for a while, lest they wander prematurely from the shelter of the nest. A very interesting biological point is that the threads of glue which bind the nest together are semi-pathological products of the kidneys, and confined to the breeding season. The stickleback's paternal care takes one's thoughts to the whimsical **sea-horse** (*Hippocampus*) (see Fig. 172), which is occasionally seen among the sea-grass and seaweed off the Channel

Islands. In this case the male takes the eggs and puts them into a capacious pocket, and carries them about till the young ones hatch out and leave his care.

While the sea-horse is a great rarity on British shores, the **pipe-fishes** (*Syngnathus*) are common; and here, again, there is paternal care. In the 'snake pipe-fish' and 'worm pipe-fish' the eggs are cemented on to the under-side of the male's body; in the 'great pipe-fish' and 'broad-nosed pipe-fish' (Fig. 169) flaps of skin from the sides, 'like an unbuttoned overcoat,' fold over and protect the eggs. This interesting series obviously leads us to the climax in the sea-horse, where a pocket has been evolved.

When there is parental care among fishes, and that is rarely, it is usually exhibited by the males. This line of paternal experiment is persisted in among *Amphibians*, but it does not seem to have proved a great success, for in higher animals the care of the young has been left, on the whole, to the mothers, except, of course, that some cock-birds take their full share of nest-making and brooding. In some cases the female fish dies soon after spawning, and this fact may throw light on the evolution of parental care on the male's part.

The solicitous persistence sometimes exhibited is altogether admirable. A male bullhead has been watched in close attendance on the egg-cluster for over a month, and the lumpsucker for five to six weeks, spent in conditions which we should call great discomfort. The lumpsucker will hurry back to his duty if forcibly removed, and he has been seen searching for a bunch of eggs which was torn off by a storm. But these are only a few glimpses of the romance of seashore fishes.

THE FISHING FROG.—On some of our coasts the angler or fishing frog is not infrequently stranded—one of the quaintest of fishes. A squat body that may be a yard long and too heavy to lift, a huge gape bordered by jaws with inward-bending, hinged teeth, and on the middle line behind the head a long fishing-rod with dangling bait-like tag of skin: these three features combine to make a grotesque! The fishing-rod is the first ray of the first dorsal fin, and it can be moved backwards and forwards, down and up, on a jointed base. Its 'bait' is a piece of flesh and skin, greenish in colour, and its dangling may readily attract the attention of fishes, for they are often interested in a moving object.

We cannot wonder that our common species should be called 'piscatorius' (*Lophius piscatorius*), for the suggestion of a fishing-rod is strong. It attracted the attention of Aristotle (384–322 B.C.), who was the first to record the belief that the lure was used to bring booty within seizable distance of the jaws. There seems no reason to doubt that the peculiar adaptation works as Aristotle supposed, but it may

be that the tongue seen in the gaping mouth is part of the bait. In some of the relatives of the angler, that have gone down to the dark depths of the sea, the lure has become a **luminescent organ,** which dangles in a very strategic position above the mouth. Thus we see specialization on the top of specialization.

The angler was not always as we see it when it is stranded on the flat beach, for its early life was in the Open Sea. We shall return to this, but the present point is that early in life it begins to be deformed, partly perhaps through some growing defect in its constitution, partly perhaps by force of circumstances. There comes about an extraordinary broadening out of the head and trunk; the tail remains ' a terrier-like stump '; the muscles are relatively small in amount and distinctly flabby. Thus the deformed animal has taken to what may be called a sluggish predatory mode of life. This sounds like a contradiction in terms, but we mean that it usually waits for its victims to come within reach.

As its name suggests it is very patient, but its big mouth, its hinged teeth, and its elastic belly enable it to tackle booty of large size, such as plaice, gurnards, haddock, squids, and even lobsters. It is not always sluggish, for it has been known to catch herring and mackerel, and even diving birds; and it does not confine itself to large animals, for it is far from despising small crabs and young fishes; but on the whole it has suited its mode of life to its deformities and waits for its food. Even when it comes to the surface it is not in a hurry except at the last moment, but as a matter of fact the angler has seldom been observed in the act of engulfing its prey.

Dr. Harry Kyle notes that the angler has often been taken when attempting to gulp cod and conger off the fisherman's long lines when these are being hauled up. In a recent article on anglers, Professor Ulric Dahlgren, of Princeton, makes the interesting suggestion that the fishing-rod, besides being a lure, may be a trigger-puller. That is to say, when some fish touches the rod there may be a stimulus to a gulping reflex on the angler's part. This may explain why the stomach often contains very unprofitable objects, such as the wooden buoys of lobster-pots. If something touches the fishing-rod the angler *must* gulp or snap. For though the squinting eyes seem to be very watchful, and Dr. Kyle credits the angler with considerable intelligence, a gulping **reflex action** cannot be gainsaid. The fish must gulp, just as we must cough when the reflex adjustment is stimulated.

As the angler is sluggish on the whole, and a large fish, the question arises how it holds its own in the littoral world, where there is so much conjugation of the verb ' to eat.' Part of the answer must be found in its inconspicuousness. The mottled dorsal surface harmonizes well with the gravel and seaweed; the shorter fin-rays behind the main

fishing-rod wave about deceptively; numerous quaint mobile tags of skin about the lips and margins complete the illusion. The angler looks like a big flat stone with a growth of small seaweeds. We have seen one in clear shallow water shuffle forwards on its strong pectoral fins and settle down on an open space surrounded by seaweed. Perhaps there is also some safety in the unusually copious secretion of **mucus** from the whole surface of the body, but little is known of this except in unnatural conditions on the deck of a trawler. More certainly safety-securing is the angler's occasional concealment of its big body by working its way into the substratum. The fishing-rod is then erected, the bait dangles, the victim draws near to inquire, and then the trap snaps.

One should not lose an opportunity of putting one's hand into the gape of a dead angler, for it is interesting to feel the **hinged teeth** bending inwards before one's fingers, and standing up, sharply resistant, when the hand is drawn out again. But this must not be done in a hurry.

The life-history of the angler is as interesting as the fish itself. The eggs are found floating in the open sea, embedded in a great sheet or ' veil ' of faintly yellowish slime, with a violet-grey shimmer. One of these veils may be thirty feet long, by two feet broad, and an eighth of an inch in thickness, and the probable use of the mucus is to secure flotation, for a time at least. There may be over a million eggs in the raft, ' so fertile be the floods in generation,' as Spenser said. After three or four weeks of development the eggs hatch, but they may have been previously separated from the main mass. In other cases even the newly hatched **larvae** may remain in the raft for a couple of days or so.

The newly hatched young one floats upside down, buoyed by its **yolk-sac,** on which it depends for nourishment. After a fortnight or so the yolk is exhausted, and the somewhat tadpole-like larva begins to swim about and fend for itself. It feeds on microscopic organisms, such as Diatoms.

In a short time the larval body begins to show extraordinary changes, which are adaptive to a prolonged **pelagic life.** The head and trunk are relatively narrowed, and long tassels grow out from the paired and unpaired fins. These serve to increase the floating power, especially when they are vibrated in the water. When they are quite still the young fish sinks slowly. The paired fins, especially the pectorals, help the tail in spasmodic darting movements in pursuit of small fry, such as copepod crustaceans. The creature has been described as ' fluttering and darting ' in the water, and it is nearly at the climax of its Open-Sea life when an inch long. All the stages have been depicted and described by Dr. Alexander Bowman, Scientific Superintendent to the Fishery Board for Scotland, and they are among the quaintest of larvae. If

one did not know, could one prophesy what they will become? They certainly do not illustrate the saying that the child is the father of the man.

In the life-history of the angler there has been an interpolation of a long pelagic larval period, partly because the Open Sea is a safer cradle than the floor of the sea in inshore waters, and partly because diffusion of the race is thus secured. But it is no easy-going life that the tasselled larvae enjoy. Their ranks are thinned by adult pelagic fishes, by larval rock-lobsters, by squids, and by sea-gooseberries, and of the million developing eggs in the purple veil only a small percentage become fishes that fish.

When the free-swimming and free-floating larva is approaching two inches in length something begins to go wrong. The head becomes relatively heavy and broadens out enormously behind the eyes, bringing them to the top; the first dorsal fin-ray begins to show a hint of the lure; the tassels disappear and small tags of skin become numerous. Although the pectoral fins have lost nothing of their strength, which they retain throughout life, it is evident that the young fish finds it increasingly difficult to keep afloat. So, as its deformity grows upon it, it sinks to the bottom, probably towards three inches in length, and then begins its somewhat lazy and possibly pensive life as a veritable angler.

THE TARPON.—Few of us can number a tarpon among our treasures, but there is something to be said for having what might be hopefully called an instalment, namely a single scale! It has a diameter greater than the palm of our hand, and it is like a plate of translucent silver. It might be compared to a herring's scale enormously magnified, and it is made of the same kind of tissue, a form of ivory, called **vitrodentine.** The silveriness is due to spangles of a waste-product called **guanin,** so here we have another instance of 'beauty for ashes.' It is interesting to peer into half-transparent fish-scales and to see the beautiful ripple-marks of growth, line upon line, year after year. Even if we are not quite sure, without further inquiry, how many rings represent the annual increment, we know that we are looking at the diary of a growing creature; and this thrills our imagination just like the rings of wood on the sawn stem of a tree, or the waves of limestone on the shell of a bivalve. We must not linger over the tarpon's scales, but it is justifiable to begin with them, for they give the living animal the sides of burnished silver to which it owes its pet name of 'silver king.' They also help in adorning the back of the fish with its magnificent royal-blue colour. A tarpon's scale is a sample of the fish in a sense that is not true of a brick and a house.

The tarpon is famous among fishermen because it gives such good sport, and, as one of the enthusiasts says, 'its size is entirely

satisfactory.' Specimens six feet long are by no means rare, and many of them weigh between one hundred and two hundred pounds. The maximum weight is said to be three hundred and eighty-three pounds, but there are some murmurs in regard to this record. We like the writer who speaks of the tarpon's ' imposing personality.'

Mere size, however, would not give the tarpon its high position among the angler's favourites. The point is that it can be taken by rod-and-reel fishing and by trolling, and that it makes a valiant fight. The Atlantic species, *Megalops atlanticus*, is fished in shallow water off the coast of Florida, Cuba, Texas, Mexico, and south to Brazil; and the sport the tarpon affords arouses the warmest enthusiasm. It seems that the tarpon likes to bask in the sunshine in the quiet waters near sheltered shores or in landlocked bays with a floor of clean sand. ' The tarpon fisherman goes out early, and casts his bait, half a mullet, upon the shallow waters. For hours he floats upon a sea of molten silver, bathed in a flood of dazzling sunshine, and at times grilling in the heat which comes with it.' This quotation is taken from a zoology book, not from a hotel-guide to Florida. Dimmock's *Book of the Tarpon* is said to be an angling classic in word and picture—an appreciation almost dangerous for stay-at-homes to read. Something must be allowed for the wonderful beauty of sea and shore in the ' ideal spots for tarpon '; but there is no doubt as to the magnificence of the fish itself. With size and spirit added to beauty of form, colouring, and movement, the result is overwhelming—especially when frail man lands his fish.

The tarpon is often called the largest of the herring tribe, but the relationship is not close. Apart from members of its own small and old-fashioned family (*Elopidae*), the tarpon stands by itself. But like the herring it is a high-strung creature, and expresses this temperament in its aërial acrobatics. Just as we call the salmon *Salmo salar*, a name that refers to its gymnastic feats, so we speak of the ' leaping tarpon.' Its activity has probably something to do with the relatively, as well as absolutely, large size of the gills, since an expanded surface for the oxygenation of the blood means abundant aeration of the engines of the body. Perhaps we do not always realize that in typical bony fishes about a third of the whole body is engine. That is to say, behind the end of the food-canal the body is sheer **muscle**, devoted to locomotion. The mythical ' man in the street ' thinks that a fish swims by its paired fins, but this is very unusual, though well illustrated by the flattened skates and rays. The **paired fins** in the bony fishes are usually for balancing and gentle steering; the locomotor organ is the posterior body, which may be popularly called the tail. The tarpon has strong tail-fins in the strict sense, but it has also a very powerful post-anal body of solid

muscles, arranged as usual in dovetailing W-shaped blocks or **myotomes.** When the fish feels the barb of the hook 'he rushes to the surface and hurls himself into the air in an amazing and sensational series of leaps in a frequently successful attempt to free himself.' As Van Campen Heilner says in a recent article, 'a flash of silver, dripping diamonds of spray from its flanks, catapulted itself into the air again and again, and yet again.' That is the proper spirit in which to write about the tarpon. The leaping fish shows extraordinary and almost incredible contortions of its body, as Mr. Dimmock's photographs show, and the angler needs all his quickness and judgment to prevent the hook from being dislodged. There are occasionally complete somersaults in the air, and the fish, if it does not escape, becomes eventually worn out with its terrific exertions.

We have spoken of giant tarpon, and we suppose that this fish, like many another, has no definite **limit of growth,** such as is normal in higher animals. We have seen a mounted tarpon in the Aladdin's Cave called the American Museum of Natural History, which must have been close on three hundred pounds. The world's record tarpon on rod and reel was taken by Mr. W. A. M'Laren, whose name bewrays him, in the Panuco River, Mexico: it weighed two hundred and thirty-two pounds! Yet the great majority of tarpon run from thirty to eighty pounds, and Mr. Heilner is probably right in suggesting that the bigger fellows lose their agility and become the prey of sharks.

Tarpon feed on small fishes, whose vitality they reincarnate. Their spawning-grounds remain unknown, but they are probably in the shallow waters of the Caribbean region, and perhaps up the rivers, where babies are sometimes found. As the adults come right up to the Atlantic side of the Panama Canal, it would be interesting to try acclimatization in the Pacific.

To conclude, in Mr. Heilner's words, 'if you love angling, pack your tackle and slip down the coast to the Caribbean coasts and try your mettle on one of the grandest of God's gifts to fishermen, that molten ball of flashing, gleaming silver, that master of aerial acrobatics, the leaping tarpon.' *Bon voyage!*

THE ROMANCE OF THE EEL.—To Dr. Johan Schmidt, of Copenhagen, we are indebted for an almost complete clearing-up of the question of the life-history of the common eel (*Anguilla vulgaris*), which has engaged the attention of inquirers since the time of Aristotle. His work, which was begun in 1904, is a fine example of patient thoroughness, and it has had its reward. It has made a connected story of one of the most remarkable of life-cycles.

It has long been known that eels do not spawn in fresh water. Those untrained observers who insist that the number of eels in an

apparently isolated pond has demonstrably increased, are failing to appreciate what young eels, or elvers, can do in the way of overcoming obstacles. On their way up from the sea the young eels can circumvent waterfalls, wriggle across a stretch of damp meadow, and swarm up a drain-pipe. In some cases there has been a confusion between eels and lampreys, as was the case, we think, in a paper read some years ago before the British Association. Eels never breed in fresh water.

Indeed, it has long been known that the full-grown eels pass in autumn from rivers and lakes down to the sea. Before they start on their journey they have undergone a constitutional crisis, marked by

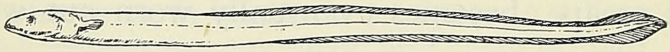


FIG. 179. A YOUNG EEL (*Anguilla vulgaris*)

an increase of carbonic acid in the blood, a shrinkage of the food-canal, an excited restlessness, an enlargement of the eye, a narrowing and heightening of the snout, and an exchange of a yellowish or greenish dress for one with a silvery sheen. The pectoral fins become darker and pointed. The big 'silver' eels prefer to travel by night, which is, indeed, the time of the eel's maximum activity in ordinary life. Their pace in the river may be thirty miles in the twenty-four hours —we saw them one evening in what might be called a tumultuous race—but the average is about a third of that. The females may be about a yard long and from six and a half to eight and a half, or even more, years old; the males do not exceed twenty inches and are from four and a half to six and a half years old. The most important catches of eels are during the seaward migration. It should be noted that some eels spend their growing period near the mouths of rivers, or in harbours and the like; but this is not the usual story.

It has also been known for a long time that myriads of small eels, or elvers, come up from the sea in spring, cylindrical creatures about two and a half inches long, and as thick as a bone knitting-needle. It was generally supposed that these were the offspring of the big eels that had gone down to the sea the previous autumn, but in 1896 Grassi and Calandruccio found that the elver stage is preceded by a leaf-like larva, transparent as glass, and about three inches long. By a striking change, involving a reduction of length and height, the glassy leaf-like larva, or *Leptocephalus*, becomes an elver. Here it should be noted that the Leptocephalus had been described as far back as 1856, but it was thought to be an independent kind of fish. It was not known as a larval eel.

The Italian naturalists came to the conclusion that the breeding-

grounds of the eel were in deep water, in the Mediterranean, and that the young larvae went through their development in the abysses, only coming to the surface when they had changed into elvers and were about to ascend the rivers. The occurrence of Leptocephali in the upper waters of the Straits of Messina was explained as due to the peculiar currents in that region, which tear up the sea-bottom and anything living there. The work of Schmidt has shown that the Italian conclusion, though a step in the right direction, was far from being correct.

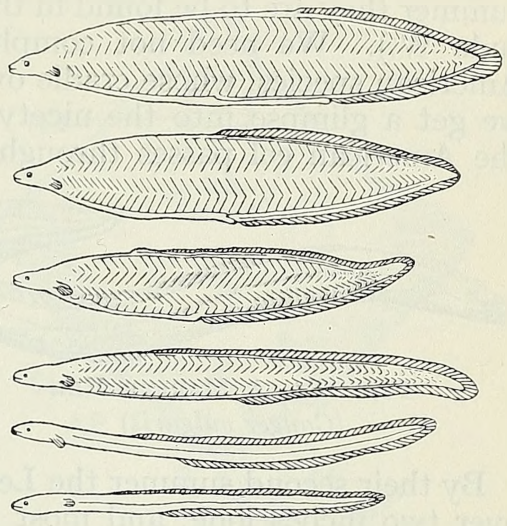


FIG. 180. STAGES IN THE DEVELOPMENT OF COMMON EEL

1, 2, 3, laterally compressed transparent Leptocephalus stages; 4, change, when about two years old, from 'knife-blade' to cylindrical shape; 5, 6, stages in growth of elvers.

Let us return, then, to the big eels, which are in process of becoming ripe. The completion of this process requires the stimulus of the sea, and not any sea will do. Thus most of the North Sea is too shallow, and where it is deep enough it is too cold. What Schmidt has shown is that the European eels, after a journey of several months, find their breeding-place in the western Atlantic, between about 22° and 30° North latitude and about 48° and 65° West longitude. The central portion lies about latitude 26° N., or approximately equidistant from the Leeward Islands in the West Indies and from Bermuda. He tells us that on one occasion, after a two hours' haul, the net brought in close upon eight hundred specimens of minute larvae—more than had hitherto been obtained in the whole course of any expedition. That single haul was enough to show that the cradle of the eels had been discovered.

It is a remarkable picture that the Danish naturalist gives of 'hosts of eels from the most distant corners of our continent shaping their course south-west across the ocean, as their ancestors for unnumbered generations have done before them. How long the journey lasts, we cannot say, but we know now the destination sought: a certain area situate in the western Atlantic, N.E. and E. of the West Indies. Here lie the breeding-grounds of the eel.' Dr. Schmidt must have experienced a thrill of triumph when he wrote that simple sentence—condensing the work of seventeen years.

Spawning begins in early spring and lasts to well on in summer.

The newly hatched larvae, about one-third to three-fifths of an inch in length, float in water-layers about 600 to 1,000 feet below the surface, in a temperature of about 20° C. They grow quickly, and in their first summer they have an average length of about an inch. They rise to near the surface (75 to 150 feet), or sometimes even to the surface itself. Aided by the eastward movement of the surface-water, they begin their journey towards the coasts of Europe. During their first summer they are to be found in the western Atlantic (west of 50° longitude W.). We need not complicate the story by referring to the American species, whose cradle overlaps that of the European eel, but we get a glimpse into the nicety of vital differences in the fact that the American eel passes through its larval life in one year, whereas the European eel requires three years. With this there is correlated, in a remarkable way, the fact that the American larva moves westwards and northwards, whereas the European larva joins the currents setting for the east.

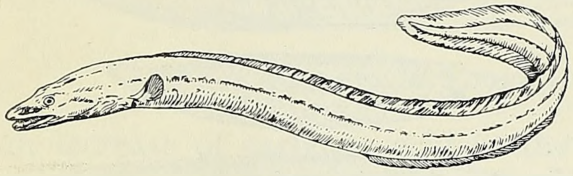


Fig. 181. A Marine Eel
(*Conger vulgaris*)

By their second summer the Leptocephali are, on an average, a little over two inches long, and most of them are in the central Atlantic. In their third summer they have arrived off the coastal banks of Europe, and they have now reached their maximum larval size, about three inches. They are still like transparent knife-blades, without any pigment save in their eyes. They swim with beautiful undulations in a leisurely fashion, and they are able to float at rest—almost invisible in the water.

In the course of the autumn and winter following their third summer a remarkable change sets in. The body is changed from knife-blade-like to cylindrical, becoming shorter and lighter in the transformation. During the crisis the creature is fasting. The result is an active elver, about three years old, and two and a half inches in length. These elvers ascend the rivers in huge numbers, forming the well-known 'eel-fare.' Sometimes the head of one is almost touching the tail of his neighbour in front, and there is a constitutional obligation (a **tropism**) to go straight on as long as the daylight lasts. The males are a little apt to lag behind, and some of the elvers, as we have already said, linger in the estuaries. The females are more strenuous and may go far inland. In Switzerland specimens have been taken in waters at an altitude of three thousand feet above the level of the sea. The throng of the eel-fare is remarkable, but still more striking is the persistence with which they overcome difficulties. They will wriggle up the moss-covered stones beside a waterfall; they will even make a

short excursion on land. And this pertinacity is exhibited after three years of a journey which may have extended over three thousand miles of sea.

When we compare the migration of the eel with that of birds, we recognize at once a great difference, that there is no return journey of the breeding eels. It seems that they all die after spawning in the distant Atlantic depths. It is well known that animals tend to go home to breed

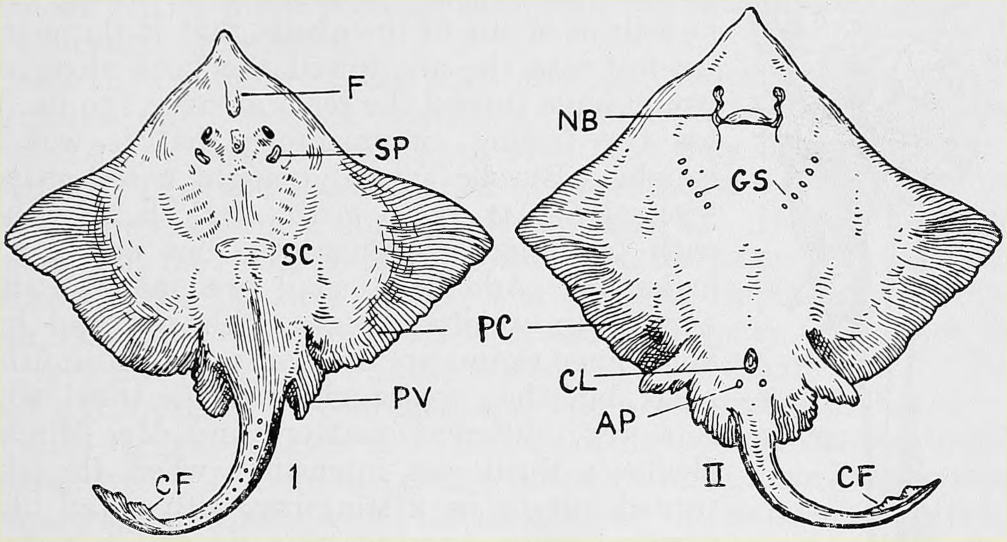


Fig. 182. External Features of a Skate (*Raia*)

I, dorsal view. II, ventral view.

F, anterior fontanelle (unroofed part of skull); SP, spiracle; SC, the supra-scapulae, two cartilages by which the pectoral girdle (PC) is attached to the backbone; PV, pelvic fins; CF, caudal fin; NB, naso-buccal groove; GS, gill-slits; CL, cloaca; AP, abdominal pores leading to body-cavity.

—the land-crabs coming from the mountains to the shore, and the carnivorous turtles from the Open Sea to the sandy beach. It is probable that the race of eels began in inshore waters, that in the course of ages some of them followed the food down to great depths, and that later on most of them took to exploring the fresh waters, just as salmon have taken secondarily to feeding in the sea. In any case the known facts stand firm, and they illumine what is perhaps the most remarkable of all life-histories.

OTHER GIANT FISHES.—Most animals have a very definite **limit of growth.** Thus there is very little variation in the size of an adult sparrow, or frog, or blue-bottle, or garden-spider. In a minority of cases, however, growth continues at a diminishing rate as long as life lasts and the supply of food is abundant. Most fishes belong to this group of unlimited growers; and we catch old, yet not senescent,

haddocks as big as ordinary codfish, salmon sixty pounds in weight, and skate over six feet long, not counting the tail.

The best fish stories since Bullen—and most of his fishes were zoologically whales—are those told by Mr. F. A. Mitchell-Hedges, in his *Battles with Giant Fish* (Duckworth, 1923). His fishing-ground was in the Caribbean Sea, and neighbouring parts of the Pacific, and he gives a picturesque account of much good sport. Thus he tells us of one of the giants that it threw itself six feet into the air, towed the boat along, and would have turned the scale at over 250 lb., but for the trifling circumstance that it was not caught. But he actually caught a red snapper 58 in. long, 41 in. in girth, 102¼ lb. in weight, with teeth like an alligator's, but nearly 2 in. in length. And what shall one say of a shark 237 lb. in weight, caught with rod and line? Some huge skates are brought into British fishing ports, but they are caught with the trawl, which is a very different matter; and Mr. Mitchell-Hedges's thrill was intensified when the skate turned out to be a **sting-ray,** with a tail like a carriage whip, bearing near its end a serrated dagger that gives one of the ugliest of wounds, apt, indeed, to be fatal. They got a female sting-ray weighing 300 lb., and it was noticed that the dagger is double in this sex. The young are born viviparously, and fully formed except that they have no dagger, which would be distinctly in the way inside the mother! Here it may be noticed that young saw-fishes have the saw developed before birth, but the weapon is covered by a sheath until the young warriors are born. This is a rather striking **ante-natal adaptation.**

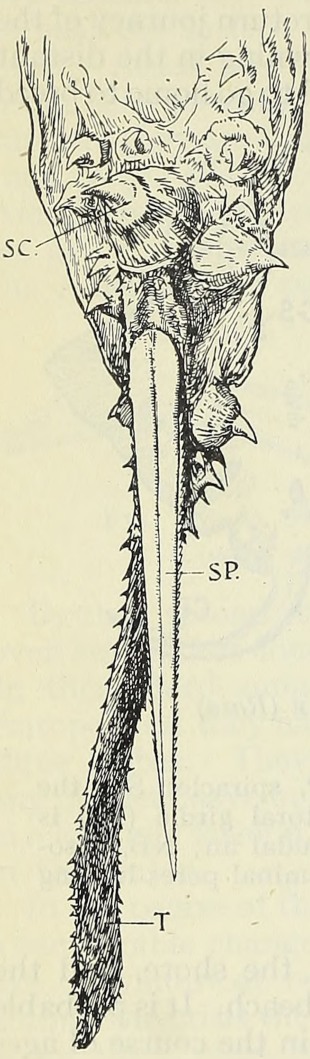


FIG. 183. TAIL OF STING-RAY

SC, placoid scale; SP, stinging-spine; T, tail.

Some of the leopard sting-rays are awe-inspiring. After hours of fighting with rod and line, the fishers landed one that was 7 ft. 6 in. across, 6 ft. 9 in. in length of body, with 9 ft. 6 in. of tail, and a weight of 410 lb.

Apart from parasites—from microbes upwards—there is very rarely any hint of constitutional disease or of pathological growth (like cancer) in Wild Nature. If such diseases emerge they are nipped in the bud. Nature is all for health; what is out of tune is eliminated. It must be noted, however, that Mr. Mitchell-Hedges found among his

big fishes, e.g. a shark of 1,460 lb. (not caught with rod and line), considerable evidence of pathological growths. The question rises whether these were in any way a tax on size, the penalty of growing too huge. It must also be remembered that sharks frequently swallow recalcitrant booty, which lacerate the viscera. Thus a swallowed globe-fish, with its parrot-beak jaws, may bite through the wall of the shark's stomach, and then through the wall of the body, thus regaining freedom. It is quite possible that such internal injuries might lead to abnormal growths.

More intelligible were the scars and half-healed wounds which the big fishes often showed externally, grim evidence of fierce battles. It is not only with molesting enemies that they fight, but with one another. Thus the observers had the good fortune to witness a battle royal between about a dozen male sand-sharks. It was the breeding season, and they had all set their fancy on the same beautiful female. 'Rushing, tearing, and rending one another, ripping out chunks of flesh, thrashing the water with their tails, the spray and spume flying in every direction'—the battle lasted for a good half-hour. 'For at least a hundred yards around, the water was red with blood.' Mr. Mitchell-Hedges believes that the fury of the bull sharks was mutually destructive. 'If there was ever a victor, he must have been so terribly maimed and mutilated as—I should imagine—to be no longer attractive to the lady of his choice.' There are some strange scenes in the drama of life.

THE TILE-FISH.—In the spring of 1882 the master of a vessel entering New York reported that he had sailed for fifteen miles through a sea covered with the dead bodies of a strange fish. His story was verified, and it was estimated that a great tract of sea, 170 miles long and 25 miles wide, off the coast of Long Island and New Jersey, was covered with dead fishes, perhaps 1,400 millions of them—*nearly as many fishes as there were people alive on the earth in* 1882.

The fishes were all the same, specimens of a Deep-Sea fish that had been discovered three years before. It received such a long name (*Lophalotilus chamaeleonticeps*) that we are almost afraid to venture on it, but it was called 'tile-fish' for short. Its length is considerably over a foot, its colours are brilliant, its flesh is firm and palatable.

Now, it appears that the home of the tile-fish was in fairly deep water, on what is called the Gulf Stream slope, and that great storms in 1882 had pushed the warm Gulf Stream off its usual course, and allowed an incursion and down-sinking of chilly water. This killed off the tile-fish in prodigious numbers, and it was thought for a while that it was completely exterminated. No specimen could be found.

In 1889, however, the United States Fish Commission reported that the Gulf Stream was returning to its old course, and one of the naturalists predicted that the tile-fish would soon be rediscovered, for it seemed unlikely that no survivors had been left. The prophecy came true. The tile-fish was trawled once more in 1892, and in a few years it was again abundant. In 1915 it was common on the market, and in the following year over ten million pounds' weight were sold.

The case is a very interesting one, for it shows how a disturbance may cause the disappearance of a fish for many years, and how a restoration of the original conditions may bring it back again from its retreats. Such a restoration has, however, not often been effected.

SALMON PROBLEMS.—Except as regards self-preservation and doggedness, we cannot credit the salmon with much in the way of brains. We wonder how many anglers, who sometimes project into the fish certain of their own good qualities, such as judgment and ingenuity, have ever looked at the famous leaper's **cerebral hemispheres,** for to an unprejudiced eye they are not much to boast of; and it is in them that the higher mental faculties have their home. The fact is that for uncountable ages the animal brain was an organ for controlling movements and receiving tidings from the outside world, rather than an organ for thinking with; and most of the cold-blooded backboned animals have a very poor cerebral equipment. But while this is true of *Salmo salar*, as of most others, we must grant it considerable individuality. The beekeepers say that one must never say ' always ' about bees, since they so often break their own rules. And so it is with salmon; they vary in characters and ways in different rivers and countries. Even when they play the same tune they differ in time. The punctuation of their life-story is variable, and thus discrepancies arise.

One of the interesting and still, we think, arguable problems is in regard to the salmon's original home. Is the salmon a marine fish, of Atlantic habitat, that has taken secondarily to spawning in fresh water, a change possibly justified by the greater safety of the developing eggs and young stages? This is the view of the best authorities, and in its favour it is usual to emphasize the fact that salmon and other salmonoids are, with few exceptions, confined to those rivers and lakes which are accessible from the seas which they now visit or in which they once were at home. If *Salmo salar* is an aboriginally freshwater fish, why is it restricted (apart from recent landlocking) to rivers, in America as well as Europe, connected with the North Atlantic? If the trout is an aboriginally freshwater fish, why is it absent from northern Siberian rivers where our pike and perch abound? If we regard the salmon as originally a North Atlantic fish, we may

place its colonization of fresh waters beside the similar adventures of the shad (belonging to the herring family) and the bass (belonging to the sea-perch family).

The other theory is that the salmon is a true freshwater fish that has taken to exploring and exploiting the sea for nutritive purposes.

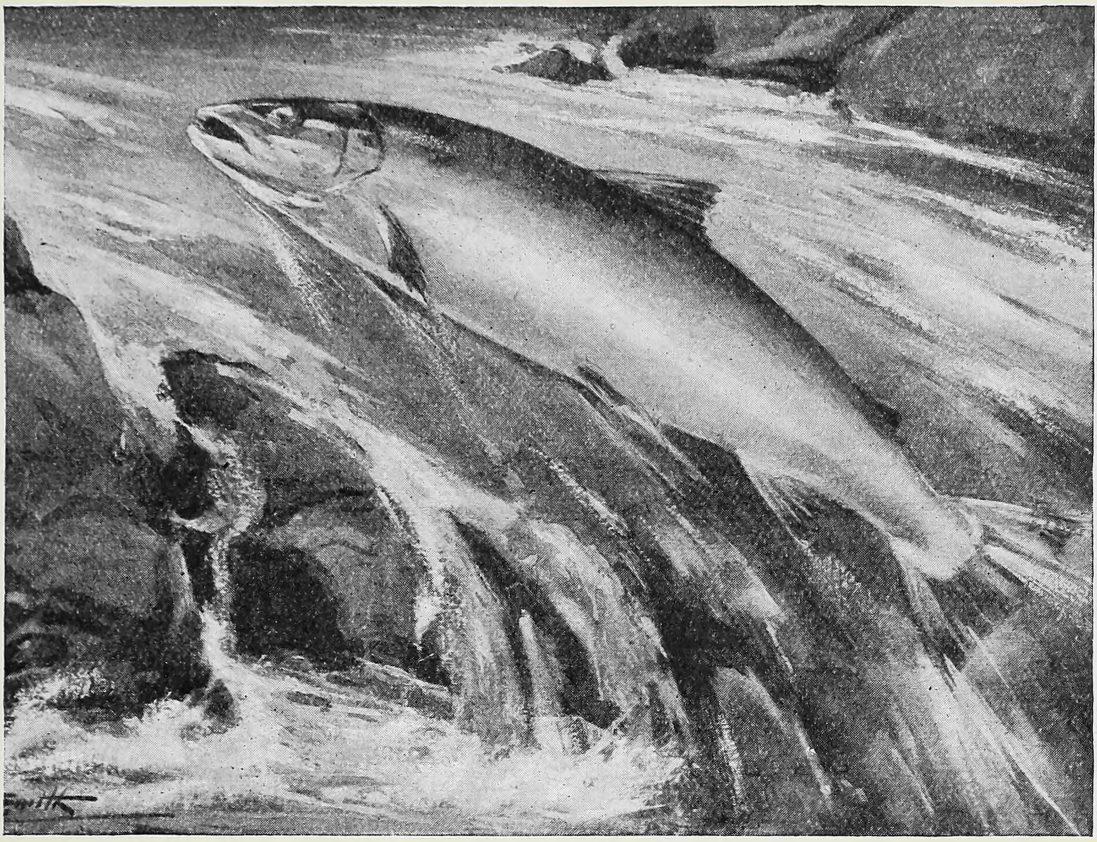


Fig. 184. Salmon Leaping a Fall

The strongest argument in support of this view is to be found in the general rule that when an animal has two very different haunts, *the spawning-ground or reproductive area indicates the original home.* Flounders may be caught many miles up a river, but they go down to the salt water to spawn; sea-snakes may be seen swimming a hundred miles from land, but they reproduce among the shore rocks; the robber-crab climbs the coco-palms, but it has to go back to the shore to breed; and so on through a long list.

Many of the older salmon problems are no longer arguable. Thus it seems certain that full-grown salmon do not feed in fresh water. That some lure may pull the trigger of their snapping instinct is obvious; but this is not ' feeding.' The weight gradually decreases when the fish leave the sea.

It is now admitted by all that salmon have a capacity for '**homing.**' That is to say, they tend to return to their own native rivers, as marking experiments have clearly proved. But there seem to be considerable differences in this homing capacity, for some salmon have been known to pass several river mouths before coming to their own, while others are misguided enough to try the Thames. What their 'cues' are remain uncertain, but the general opinion is that the selection is guided by smell or by some related chemical sense. It is probable that the salmon in the sea does not rove very far from 'its own river.'

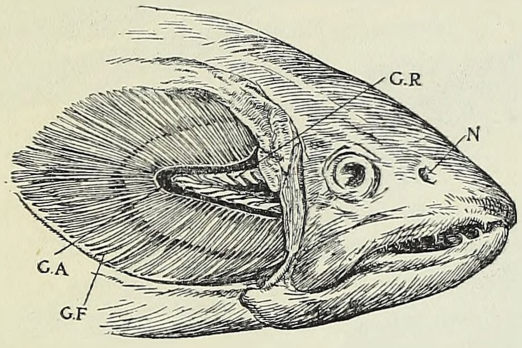


FIG. 185. HEAD AND GILLS OF THE SALMON (*Salmo salar*)

N, nostril; GR, rudimentary gills; GA, gill-arch; GF, gill-filament.

One cannot but ask what immediate impulses lead to the often exhausting journey against the stream. It is not enough to refer to the spawning, for that may not occur for months, and many fish that ascend the river for a considerable distance drop back again for another period of residence in the sea. Perhaps one should think of the 'running' salmon as a creature that has accumulated by abundant feeding a great store of energy that tends to overflow. Perhaps there is also a reproductive restlessness, when the running salmon is already sexually mature. No doubt there is an engrained **instinctive urge**, but this must have its immediate liberating stimulus. Moreover, the historical evolution of all these urges has to be accounted for; there must have been individual physiological causes and justifications before the racial engraining could be effected. The same kind of problem arises in regard to the marked restlessness of the silvery *smolts* (young stages of the salmon) when they are over two years old. Poetically, we may say that they hear the call of the sea, the ancestral home of their race, but we wish to be able to translate this into concrete physiological terms. Not that we wish to deny them the possession of a piscine mind as well.

The salmon affords some good instances of **variability** in the punctuation of a life-history. That is to say, individual arcs on the trajectory or **curve of life** may be lengthened out or shortened down, a fact of considerable interest in connection with the evolution of related species or even genera. Thus, as is pointed out by Dr. Tate Regan, the Director of the British Museum (Natural History), and one of the most distinguished of ichthyologists, the Pacific salmon (*Oncorhynchus*) is like an exaggerated form of our salmon—e.g. in its crowded ascent

of the rivers, in the changes that mark the spawning period, in the amount of germinal material involved in the reproductive sacrifice, and in the fact that the spawning is always fatal. In the case of our salmon there are records of male *parr* (first stage after the fry) being reproductively mature and of female smolts having ripe eggs; and it is a very familiar fact that the fish may spawn as a *grilse*, that is before it has quite put on all the characters of an adult salmon. These 'temporal variations,' eccentricities in the tempo of life, seem to us to have great evolutionary interest.

An easy problem would be to determine the nature of the influence—almost certainly a **reproductive hormone**—which induces in the mature male salmon a prolongation of the snout and lower jaw, and an upward bending of the latter. In some old males it is very marked, but we do not know that its physiological cause has been studied. And is its use as certain as some anglers believe? There are plenty more salmon problems—we do not require to fish for them.

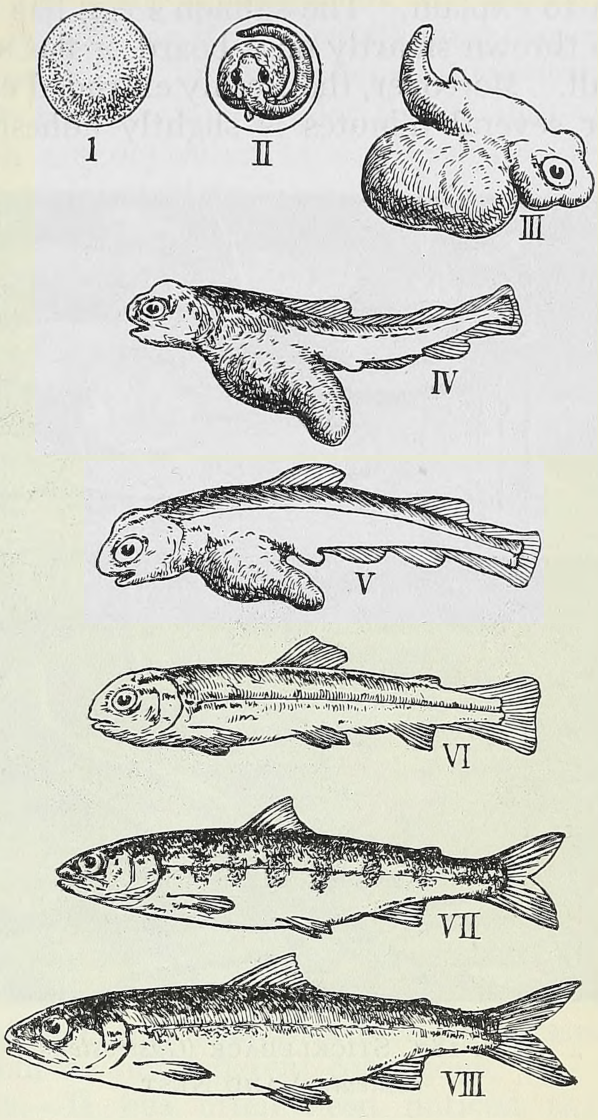


FIG. 186. LIFE-HISTORY OF THE SALMON
I, fertilized egg; II, egg just before hatching; III, the newly hatched fish ('alevin'); IV, V, larval salmon nourished from yolk-sac, which diminishes in size as the fish grows; VI, salmon fry with yolk absorbed (about six weeks old); VII, somewhat older fish; VIII, adult.

THE SALMON'S EGG.—The salmon deposits her eggs in a suitable stretch of gravel and covers them by strokes of her tail, thus forming the 'redd.' If the eggs were not quickly covered they would be devoured by trout and other enemies, as, indeed, too many of them are. But how is it that they are not crushed by the shifting of the gravel, or washed downstream by floods? Mr. Calderwood, the Inspector of Salmon Fisheries for Scotland, has answered these questions in one of

his reports. He points out that the salmon does not choose ground that is of a shifting character. But there is more than this, as he goes on to explain. The salmon's egg has remarkable properties. If one be thrown smartly on a board or flat stone, it rebounds like a rubber ball. Moreover, the freshly extruded egg swells after fertilization, and for several minutes is slightly adhesive. These two characteristics taken together work very well. The egg may be compared to a gummed ball that rebounds off objects, and yet when once at rest will adhere to them, until, as it were, the gum is washed off. 'In this way the egg readily rebounds from stones which strike it, but on falling against stones by reason of its own specific gravity, while the redd is being covered, is not very readily detached by the current. By the time the redd is completed, the adhesive character has passed away.' The eggs lodge in the interstices between the stones, but they never seem to be caught between stones and crushed. They shoot into safety before the stone reaches them. Life is often delicately balanced.

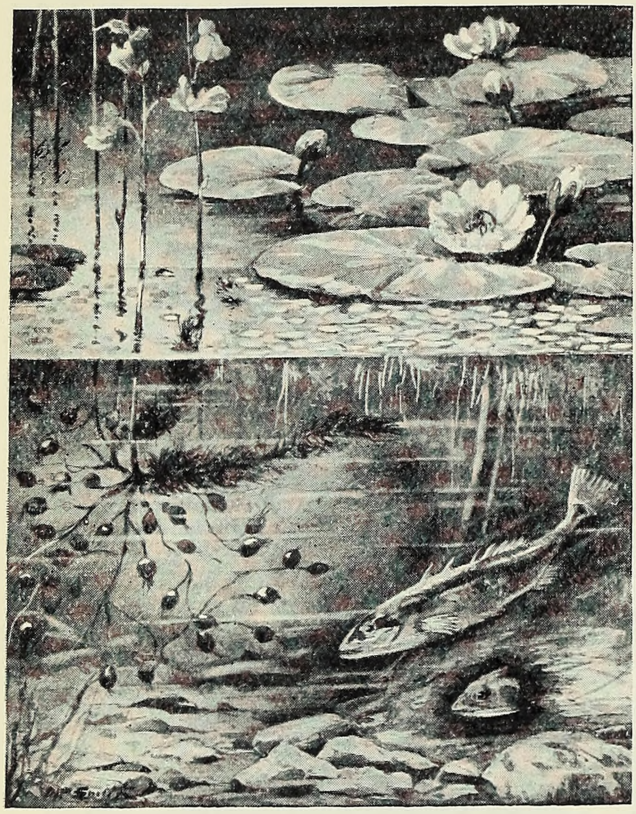


FIG. 187. STICKLEBACK (*Gastrosteus aculeatus*) AND NEST

STICKLEBACK'S EGGS. — The male of the common three-spined stickleback (*Gastrosteus aculeatus*) makes a little nest of pieces of freshwater plants, fastened by glutinous threads secreted from the kidneys at the breeding season—a good instance of a disease-process that has become in this case normal. Several females lay their eggs in one nest, which is valiantly guarded by a single male; and there are eventually 120–150 eggs altogether. This is a very small number for a fish, but the reproductive economy is obviously bound up with the high development of **parental care.**

W. Köhler has recently taken the trouble to count the eggs in the ovary of a mature stickleback, and found in March 302 that were ripe, and at least as many that were unripe. Three other females contained

100, 200, and 228 ripe or nearly ripe ova—much larger numbers than were previously reported. Since a well-filled nest contains 120–150 eggs, it seems probable that if the male is **polygynous,** the female is **polyandrous.** In other words, it looks as if the female must deposit eggs in several nests. One would like to know definitely whether the female survives the reproductive strain. Köhler thinks that the unripe eggs observed in March are deposited at a *second* breeding period in July. He notes that male sticklebacks were seen guarding their nests in July and August, while swimming around them there were half-grown individuals, presumably of the first brood.

MENTALITY IN FISHES.—It must be admitted that fishes usually hide their mental light under a bushel. They are very effective in scores of ways, but when we subtract from their behaviour all the reflex actions and tropisms, is there much left? Then we have to deduct the routine instinctive capacities seen, for instance, in the male stickleback's nest-building; for, though there may be a spice of intelligence in some forms of predominantly instinctive behaviour, the two cannot be confused. Intelligent behaviour requires to be learned; it implies perceptual inference; it means some understanding of the situation. We look for it most hopefully when the behaviour of the individual animal shows **plasticity** according to circumstance. In our search we cannot find a better guide than Dr. Harry M. Kyle's most excellent *Biology of Fishes* (1925), the best general book on fishes as yet published —in this country, at least. He has a capital story of two sharp-shooting spitting-fishes (*Toxotes jaculator*) that seemed to invent the game of shooting the spectators with viscid drops, now on the eye and again on the nose, and once more on the chin. But we confess we should like to have seen this with our critical spectacles on. There is also the high-spirited maker of the ' bubble nest '—a floating island that buoys up the eggs; and this original creature is particularly interesting because of the **variability** of his behaviour to suit different conditions.

THE SILVERINESS OF FISHES.—It has often been noticed that fishes from open water are very silvery, especially on their under-surface and on their sides. This is particularly true of fishes that swim near the surface, whether in the sea or in lakes. Herring, mackerel, and flying-fishes are good instances. What is the practical meaning of this silvery appearance which is generally absent in fishes that live in very deep and dark waters?

The probable answer has been suggested several times—that the silveriness gives its possessors a Gyges' ring, a power of becoming invisible. Thus a naturalist called Popoff pointed out some years ago that from a certain depth the surface layer, with the light sky above, is like a mirror, and that the more silvery a surface fish is, the more difficult is its detection by the hungry eyes of its enemies looking up

from below. Similarly, to a solan goose's eyes looking down from above, a fish with a dark upper-surface may be inconspicuous against the background of the dark water. This is step one.

We know that the silvery appearance of fishes is due to minute grains, or plates, or crystals of the waste-product called guanin. These usually lie as glistening spangles in special cells of the skin. According to the way in which these spangles are shaped and arranged, the fish is white, or silvery, or rainbow-like. The other colours of fishes are due to pigments or coloured substances, comparable to paints, some red, some orange, some yellow, and some black. These **pigments** are contained in very beautiful and somewhat star-like cells of the skin. Other colours may be produced by blending pigments; thus yellow and black, for instance, give green. The silveriness is not due to any white substance or pigment—it is due to the reflection of the light from the spangles of waste. When there is only guanin, the skin is white or silvery; when there are pigments as well, the fish has other colours to which the crystals often give a wonderful brilliance, as in rainbow-trout or in coral-fishes. This is step two.

A Swiss naturalist, Murisier by name, has made some very interesting observations on the colours of young lake-trout. He divided a number of newly hatched fry into two lots, which he kept in quite similar conditions, except that those in one aquarium got plenty of light and had a white tile floor, while the others lived in darkness over a dull black floor. He kept the young trout for nine months, and found that the well-lighted ones showed brilliant silveriness on their under-surface and sides, while their brothers and sisters who had grown up in obscurity were sombre in colour and had no silver. The fact seems to be that when there is no screen of pigment-cells the light penetrates further into the fish, and this seems to provoke the formation of many surface spangles. The more light, the more silver; and we are thus brought nearer an understanding of the frequency of silvery fish in the surface waters, and why trout of different lakes and rivers have different colours.

But what is it that keeps the ordinary coloured cells from appearing as usual and forming the beautiful screen which we all admire in the trout? The answer is somewhat difficult. It seems that the bright light, especially that reflected up from the floor of the aquarium, affects the eye of the fish in a peculiar way, and brings about a sort of nervous excitement that keeps back the ordinary process of colouring. Part of the proof of this is very convincing, for *blind trout do not become silvery on the white floor*. This is the third step in our understanding of the silveriness of many surface fishes.

Thus we know, first, why the silveriness is useful; second, to what the silveriness is due; and, third, the external circumstances that

decide the amount of silveriness a particular fish is to have. There is still much more to know before the problem of the silver fishes becomes quite clear, but we are getting on.

A FISH THAT PUFFS OUT LIGHT.—Some luminescent organs, as in certain cuttlefishes, owe their light-producing power to the presence of ' phosphorescent ' bacteria, like those we see shining on haddocks hung up to dry. In many other cases, however, the luminescence seems to be produced by the animal itself without the aid of any partner-bacteria. In his book on *Animal Light* (1919) Professor Newton Harvey distinguishes two kinds of intrinsically luminous organisms: (*a*) those in which the oxidizable material is oxidized within the cell where it is formed, and (*b*) those in which the material is

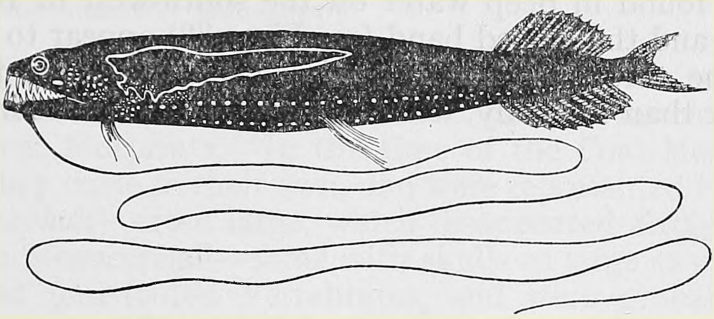


FIG. 188. *Lamprotoxus flagellibarba*

secreted to the exterior and oxidized outside the cell. Hitherto, all luminous fishes that are intrinsically luminous have been ranked in the first group, but Mr. C. F. Hickling has had the good fortune to find that a Macrurid fish called *Malacocephalus laevis* secretes luminous material which is oxidized outside the cell.

The fish in question occurs along the outer edge of the continental shelf from Ireland south to Morocco, and is taken in considerable numbers by the deep-water trawlers in depths of over a hundred and fifty fathoms. The luminous organ is an inturned plaited skin-gland, which lies in the thickness of the body-wall between and behind the pelvic fins. As it was well developed in the smallest specimens collected, it cannot have any sexual significance. It lies between the strong muscles of the body-wall and may have a special muscular sheath apart from these. ' Contraction of these muscles would cause the secretion to be shot out, and its use would seem to be exactly analogous to the ink-sac of Cephalopods, but, whereas the latter emits a cloud of ink, this fish emits a cloud of light.' When a large specimen was thrown overboard alive, it emitted, according to Captain Jones, a cloud of fire, which spread ' like a dinner-plate,' and apparently remained visible for some time. There is no evidence that the luminous secretion is used as a flash-light to enable the Malacocephalus to see

its way in the dark water, but it may be attractive to the crustaceans on which the fish chiefly feeds. Or it may be that when the creature is pursued by a hake or some other piscine enemy, it emits a puff of light and makes off in a different direction. Perhaps the hake pauses to investigate the luminescent nimbus, and, before its research is finished, the light-puffing Malacocephalus is far away. We do not believe much in the intelligence of fishes, and the name *Malacocephalus* means 'soft head'; but as to the actual light-production, it seems to be due to a reaction wherein a substance, **luciferin,** is oxidized to **oxyluciferin** in presence of the enzyme **luciferase,** with emission of cold light.

Another queer fish is *Lamprotoxus flagellibarba,* which may occasionally be found in deep water off the south-west of Ireland. The small spots and the looped band (see Fig. 188) appear to be luminous organs. The thread or barbel arising from the lower jaw is many times longer than the body, which is about seven inches in length.

CHAPTER XVIII

AMPHIBIANS

A dwindled race—Different forms of Amphibians—Acquisitions made by Amphibians—General characters of Amphibians—Compared with Fishes—Classification of Amphibians—Amphibian evolution—Experiments in respiration—Experiments in reproduction—Some notable Amphibians—Newts—The story of the Axolotl—Salamanders—The story of Proteus—The Frog's year—Blindworms—The ancestral Mud-puppy.

A DWINDLED RACE.—Amphibians emerged in the time of the Old Red Sandstone (Devonian), but the earliest forms are known only from their footprints. In the time of the Coal Measures (Carboniferous) they came to their own, and were represented by numerous forms (*Stegocephali*), often large, which disappeared altogether in the Trias. These Stegocephali—some with skulls as large as a donkey's—were the first four-footed Vertebrates, and were probably evolved from fish-ancestors (*Rhipidistia*) related to the mud-fishes or double-breathers. It was from among the Stegocephali that reptiles probably had their origin.

When we think of modern Amphibians, such as frogs and toads, newts and salamanders, we feel at once that we have to do with a dwindled race. It is true that the giant salamander of Japan (*Cryptobranchus maximus* or *japonicus*) may attain to a length of five feet three inches, but this is a monster among modern Amphibians. The great bull-frog of North America (*Rana catesbiana*) has a body-length of five to seven inches, and as much again would have to be added if the hind-legs were stretched out behind. But this is obviously a very small animal compared with such a reptile as a crocodile, or with some of the extinct Stegocephali which reached a length of six feet. *Modern Amphibians represent a dwindled race.*

DIFFERENT FORMS OF AMPHIBIANS.—The oldest Amphibians (among the Stegocephali), the first four-footed animals, were newt-like or lizard-like in form, and that shape is seen to-day in our newts and salamanders. The body is elongated, the tail is well developed, the limbs tend to be weak. In frogs and toads, however, the form is very different, for the tail disappears at the end of the larval or tadpole period, the body is squat, and the hind-limbs are strong for swimming, leaping, and climbing. Altogether different again are the limbless blindworms (*Caecilia*) which burrow in the earth in warm

countries (such as India, Ceylon, Sumatra, South America, Africa), and have a marked external resemblance to earthworms. Thus there are *three chief shapes, newt-like, toad-like, and worm-like.*

ACQUISITIONS MADE BY AMPHIBIANS.—Great footprints, sometimes about six inches long, are occasionally found in Devonian rocks in England and on the Continent. It is supposed that these are the footprints of an extinct amphibian, but nothing is known of the animal that made them, except that it has four fingers and five toes. But in some other cases in Carboniferous rocks the remains of toed skeletons are found which are in some ways like our modern Amphibians. So it is safe to say that Amphibians were the first animals to gain fingers and toes. Fishes have limbs or paired fins, but they are without **digits**, which must therefore be regarded as an Amphibian gain. The possession of toes meant the power of gripping things, of climbing, of lifting food to the mouth, and of feeling objects in three dimensions. It was a great acquisition.

If we suppose that the first Amphibians, which are only known as fossils, were in a general way like the modern Amphibians, we may say that Amphibians gained:

(1) **True lungs**, growing out ventrally from the beginning of the food-canal.

(2) **Posterior nostrils**, opening from the nasal chamber into the mouth.

(3) **A three-chambered heart**, with pure blood as well as impure blood.

(4) **A movable tongue**, unlike the non-muscular tongue of fishes.

(5) **Vocal cords**, able to produce sound when the outbreathed air passes over them.

In the double-breathing fishes or *Dipnoi* there is, as we have mentioned, a lung arising as a transformed swim-bladder. The heart is almost three-chambered, for there is an incomplete partition in the receiving chamber or auricle. There is also a single large vein bringing impure blood back to the heart from the posterior body; it is called the **post-caval** or **inferior vena cava** and is present in all animals, including Amphibians, from mud-fishes to man. The *Dipnoi* have also many-celled glands in their skin, unlike most of the skin-glands in other fishes which are single goblet-like cells making slime. These many-celled or multicellular skin-glands are well developed in Amphibians and in those higher Vertebrates, like Mammals, that have glandular skins. We are giving these details because they show so clearly that the Mud-fishes or *Dipnoi* link ordinary Fishes on to Amphibians. They have a lung, an incipiently three-chambered heart, an inferior vena cava, and multicellular skin-glands. We are not

saying that the Mud-fishes are the direct ancestors of the Amphibians, for they seem to be on a side-track; but the facts show that the Mud-fishes made or began to make certain acquisitions which the Amphibians carried to a greater perfection. *The Mud-fishes link ordinary Fishes to Amphibians.*[1]

GENERAL CHARACTERS OF AMPHIBIANS.

(1) In most cases the skin is quite naked and is rich in glands.

(2) With very few exceptions the young forms live in the water and breathe by gills. These are sometimes retained all through life.

(3) In almost every case the adults breathe by lungs, and the nostrils, through which the air enters, open into the mouth.

(4) In most cases there are two pairs of limbs, and they have distinct fingers and toes.

(5) If there are unpaired fins, as in some newts and in tadpoles, they are always soft, not supported by fin-rays as in fishes.

(6) The skull has two knobs or *condyles* for working against the first vertebra. Birds and reptiles have one, mammals two.

(7) The heart is three-chambered, with two receiving chambers (or *auricles*) and one driving chamber (or *ventricle*); the left auricle contains pure blood from the lungs; mixed blood goes to the body, not pure blood as in birds and mammals. Amphibians are cold-blooded.

(8) The food-canal ends in a common chamber or cloaca, into which there also open the ducts from the kidneys and the ducts from the reproductive organs. A peculiar bladder grows out from the hind region of the gut, apparently corresponding to the birth-robe called the **allantois** in reptiles, birds, and mammals.

(9) The eggs are small, numerous, usually pigmented, without shells, and with yolk towards one pole. They are almost always laid in the water and hatched there, but in a few cases, as in salamanders, the eggs hatch inside the mother and the animals are viviparous. In almost all cases the cleavage or segmentation of the fertilized egg is total and unequal.

(10) The young forms are usually larvae, in some notable ways different from the parents, as in the tadpoles of frogs. In other words, there is usually a **metamorphosis** in the life-history.

AMPHIBIANS COMPARED WITH FISHES.—Amphibians agree with Fishes in having gills, in young stages at least; in often having a sensory lateral line, especially in the larvae; in having only ten pairs of nerves issuing from the brain, instead of the twelve pairs usual in

[1] The Mud-fishes must not, however, be regarded as representing ancestors of *Amphibia*; they are rather collateral descendants of common ancestors.

higher animals; and in having no ' birth-robes ' or foetal membranes such as are developed in reptiles, birds, and mammals. The tadpole of a frog is for some weeks fish-like in having a two-chambered heart, with one artery leaving it and carrying impure blood to the gills. Moreover, the tadpole has an unpaired fin on its tail, and the tongue takes some time to become movable. *Although Amphibians mark the transition from water to dry land, they have not got rid of all traces of their fish-ancestry.*

But to see how Amphibians have advanced above the fish-level, we may show some of the contrasts in parallel columns.

Fishes	Amphibians
Gills last through life.	*Gill may disappear in adult life.*
Rarely does the swim-bladder become a lung.	*In all normal Amphibians there are lungs in adult life.*
The heart is two-chambered (incipiently three-chambered in the Dipnoi).	*The heart of the adult is three-chambered.*
The unpaired fins are supported by fin-rays.	*Unpaired fins, if present, have no fin-rays.*
There are usually scales.	*There are rarely any scales.*
There are no posterior nostrils.	*There are posterior nostrils.*
The limbs are fins.	*The limbs have fingers and toes.*

As we have seen, some of the characters of the Mud-fishes lessen the gap between ordinary Fishes and Amphibians. The important fact is that while Amphibians mark a great advance—the beginning of the conquest of the dry land—they are nearer to Fishes than to Reptiles. *Fishes and Amphibians are linked together; and so are Reptiles and Birds.*

CLASSIFICATION OF AMPHIBIANS.—The most ancient Amphibia are the extinct Stegocephali whose skeletons are known from the Carboniferous to the Upper Trias. Many of them had well-developed skin armour, especially on the head (*stegos*, roof; *cephale*, head); and they may be conveniently separated off from the soft-skinned living amphibians to which they give rise. To these, with living representatives, we confine our survey, that is to the three orders: (I) limbless *Caecilians* (the blindworms), (II) tailed *Urodela* (newts and salamanders), and (III) tailless *Anura* (frogs and toads).

First Order: Caecilians or Apoda or Gymnophiona

These worm-like or snake-like burrowing animals, often called blindworms, are peculiarly *old-fashioned* types. Thus the archaic skeletal axis, the *notochord*, is largely persistent. In many other respects they are remarkably adapted to *subterranean* life, e.g. in the

absence of limbs and girdles, and the covering-up of the small functionless eyes. In some other features they are simply *peculiar*, e.g. in having a protrusible tentacle in a pit behind the nostril. Examples: *Caecilia* (South America); *Ichthyophis* (Ceylon, India, Malay); *Hypogeophis* (East Africa); *Siphonops* (America) without any scales at all.

Second Order: The Tailed Amphibians, or Urodela

The newts and salamanders and their relatives, with a distinct tail persisting through life, and therefore with less metamorphosis than frogs and toads display.

(1) The family **Amphiumidae.** The *Amphiumidae* include the largest living amphibian, namely the giant salamander (*Cryptobranchus maximus* or *japonicus*) of Japan. It lives in the cold, shaded waters of mountain streams, and has been known to reach a length of five feet three inches.

Another species, *Cryptobranchus alleghaniensis*, popularly called the 'hell-bender', occurs in the rivers and streams of mountainous regions in the eastern United States. It may reach a length of nearly eighteen inches. It feeds voraciously on worms and fishes.

In the same family is the so-called 'rice-eel,' *Amphiuma means*, found in swamps, sluggish streams, and the ditches of the rice-fields in the south-east States. It may attain to a length of three feet. It feeds on crayfishes, various molluscs, and small fishes. The limbs are very small and weak, with two or three reduced digits.

(2) The family of **Salamanders** and **Newts.** This family (*Salamandridae*) includes the majority of the tailed amphibians. The gills disappear in the adults, whereas they persist in the families (3 and 4) represented by *Proteus* and *Siren*.

The true salamanders occur in Europe and western Asia, and the best known is the spotted or fire salamander (*Salamandra maculosa*); usually about five inches long, with a livery of black and yellow. The genus *Triton* or *Molge* includes the newts in the stricter sense, with a much-compressed tail. There is often a median dorsal crest in the males at the breeding season, as in the British *Triton cristatus*. After the breeding season it is usual for newts to become very terrestrial.

This family also includes the American axolotl or *Amblystoma* type, which sometimes retains its gills throughout life, and *Desmognathus fuscus* of mountain streams in the eastern United States, which not only loses its gills as usual, but its lungs as well.

(3) The family of **Proteidae.** This family is characterized by the persistence of three pairs of external gills and the usual two pairs of limbs. The famous blind *Proteus* of Dalmatian caves has an interesing

counterpart (*Typhlomolge*) in Texas. Another genus is *Necturus* of the eastern United States, about a foot long, with functional eyes and well-developed limbs.

(4) The family of **Sirenidae.** This family is marked by the persistence of three pairs of gills, and by the disappearance of the hind-legs. The American 'mud-eel,' *Siren lacertina*, reaches a length of over two feet, about a third of this going to the laterally compressed tail. The gills of the young forms retrogress, but obtain a new lease of life later on.

The Third Order: Tailless Amphibians, or Anura

These are the frogs and toads, which have not in adult life any tail, or gills, or open gill-clefts. The squat shape of body is familiar, and with this is associated the small number (five to nine) of vertebrae. There are no ribs except in one family. There are always two pairs of limbs, strong when compared with those of the tailed *Urodela*. The majority have a tongue as in the toothed frogs (*Rana*) and the toothless toads (*Bufo*); but the Surinam toad (*Pipa americana*) and the African *Xenopus* must be kept by themselves, forming a tongueless minority.

In the South American horned toads (*Ceratophrys*) some species have an upright flexible process or horn, which rises from the eyelid, and some have a dorsal shield which is formed from the coalescence of bony scales formed in the lower stratum of the dermis and subcutaneous connective tissue. This strange case leads one to mention a Cameroon frog, *Astylosternus robustus*, which has numerous hair-like filaments on the sides and thighs of the males. These lead our thoughts to the true hairs of mammals.

AMPHIBIAN EVOLUTION.—Our general view is that amphibians, in the form of certain generalized *Stegocephali*, emerged from a fish-stock (*Rhipidistia*) among the fringe-fins. Among living fishes their nearest relatives are probably the mud-fishes or *Dipnoi*, which have lungs as well as gills.

The great step of advance made by amphibians was the colonization of the dry land; but most of them have to go back to the water to breed, and most of them have an aquatic larva.

There is evidence that certain generalized pioneer *Stegocephali* gave rise to the newts and salamanders (*Urodela*) and the old-fashioned blindworms (*Apoda*). The same should probably be said of the frogs and toads (*Anura*), which appeared much later (in the Eocene,) but no connecting-links are known.

If the amphibians were the first Vertebrates to make much of dry land, we must expect to find hints of adaptations that helped them to

get a footing and to keep it. Like all pioneers they had to live dangerously, and some of them found relief in compromise. Thus the blindworms became burrowers; some newts found refuge in mountain streams or in caves; some frogs and toads became arboreal. Most amphibians live quietly; many are nocturnal; and the general loss of the ancestral (Stegocephalian) armour is in some measure made up for by the unpalatability of the secretion from the skin-glands. The majority are small. Some can efface themselves by colour-change.

Amphibians often show hints of their insecure foothold (though there are 900 or more living species) in their winter lethargy, and in being able to live for long periods without food. But the stories of 'toads within stones' are due to faulty observation. Many of them are also helped by their long bill of fare, but the majority are uninterested in food that is not alive and moving. With few exceptions, amphibians have a constitutional antipathy to salt, and are therefore absent from oceanic islands, which would only be reached on floating trees and the like. In estimating their chances in the struggle for existence, this inability to stand salt water must be put on the minus side, but their ability to live in fresh water as well as on dry land, or up a tree, is a large plus. Finally, we may notice in this connection that many amphibians show a great power of repairing external injuries, e.g. to limbs and tail.

EXPERIMENTS IN RESPIRATION.—If we use the word experiment not for individual tentatives, but for racial changes—some successful and some not, and others still on trial—we may speak of the amphibians as very **experimental.**

Thus as regards respiration what do we find? Frogs and toads breathe by gills in their larval (tadpole) stages, by lungs as adults, and through the skin always. But an adult frog in a lethargic winter rest may breathe entirely through its skin—the most primitive of all methods, which earthworms and leeches familiarly illustrate. Moreover, in the Surinam toad (*Pipa*), where the eggs develop in pockets in the skin of the mother's back, the tadpole stage has been suppressed, and there is no trace of gills.

Most newts have well-developed gills in their juvenile stages, and lose them later on. But forms like *Proteus* and *Siren* retain them throughout life, though lungs are also developed and the primitive cutaneous respiration persists. The axolotl may keep its gills in adult life, or lose them entirely, according to circumstances. Not a few adult newts are lungless, and since they have parted with their gills as well, they must be dependent on the gaseous exchanges effected through the skin and perhaps also through the pharynx-wall and other parts of the food-canal.

In Caecilians, which have become burrowers, there are gills in the

larvae, in some cases at least, but these gills have been, so to speak, shunted back into the embryonic period *before* hatching.

Very interesting is the early respiration of a little tree-frog of Martinique (*Hylodes martinicensis*), for there is a suppression of both tadpoles and gills. About two dozen eggs are laid in the axil of a leaf and surrounded by a foam-like mass, over which the female mounts guard. The young ones, still within the egg-shell membrane, seem to breathe through their tails, which have a rich blood-supply. The exchange is between the blood-vessels and the oxygen in the foamy mass. In about three weeks there is hatching, and tiny frogs, about one-fifth of an inch in length, hop away, showing a minute white tail-stump which is completely absorbed in a few hours.



FIG. 189. TREE-FROG (*Hylodes martinicensis*)

The black salamander (*Salamandra atra*) of the Alps lives where pools of water are scarce, and instead of bringing forth gilled young ones, as its relative the spotted salamander does, it produces lung-breathers, and only a pair at a time. But the unborn young have gills that are pressed against the wall of the oviduct. This is very richly supplied with blood-vessels, and it seems that the young absorb both oxygen and food from crowds of red blood corpuscles which are discharged into what may be called the uterus. It is said that the unborn young may also feed on the débris of unsuccessful eggs and embryos.

EXPERIMENTS IN REPRODUCTION.—In most cases the eggs of amphibians have a delicate membrane, and are liberated in the safe cradle of the water, often surrounded by protective jelly. Frogs deposit their ova in great masses; toads form long double strings. Those of newts are fixed singly to water-weed and the like, and those

of tree-toads to the under-side of leaves. A blindworm may coil round a small clump deposited in a burrow in the ground.

But the note of strangeness is sounded when we take account of cases like the following. In the Surinam toad (*Pipa americana*), the large eggs are fertilized internally and placed by the everted cloaca of the female on its back, the male apparently helping in the process. The skin becomes much changed—partly, no doubt, in response to the strange irritation—and each fertilized ovum sinks into the skin, which forms a little pocket, closed by a gelatinous lid. In these pockets the embryos develop, perhaps absorbing some nutritive material from the skin. They are carried about for a while and then liberated as miniature adults.

In the ' marsupial frogs ' (*Nototrema*) of South American forests, the female has a dorsal skin-pouch, usually opening backwards near the cloaca. Into this pocket the eggs are somehow passed, perhaps with the male's assistance. The eggs develop into tadpoles, sometimes with strangely modified external gills, but sometimes with none. In some species the metamorphosis is completed in the pouch; in others there is an emergence of tadpoles, which make for the water. In the pygmy Nototrema of Venezuela, which is only an inch in length, the eggs are only four to seven in number, and the opening of the pouch is a longitudinal slit.

In Darwin's little frog, *Rhinoderma darwinii*, found on the *Beagle* voyage in shady woods in Chile, the male carries a few eggs in his capacious croaking-sacs. Nearer home is the nurse-frog (*Alytes obstetricans*), not uncommon in some parts of the Continent. The male manages to get the ova attached to his back and about his hind-legs; he buries himself in damp earth, coming out at night to feed and to moisten the eggs with dew or water. Eventually, when the embryos have almost completed their slow development, he plunges into the water and is freed from his living burden.

Such are a few of the experiments that amphibians have made in connection with reproduction. We may also mention that while the male frogs and toads fertilize the ova externally, just as they are laid by the females, the fertilization is internal in most newts and salamanders, and what finds entrance into the female cloaca is a **spermatophore** or packet of sperms, which the male liberates in the vicinity of the female.

Some Notable Amphibians

NEWTS.—The name 'newt' is strictly applied to species of the genus *Triton* or *Molge*, but there is strong reason for extending it to related forms. There are three British species: the common newt

(*Triton vulgaris*), the webbed newt (*Triton palmatus*), and the crested newt (*Triton cristatus*). In the first and third in particular the breeding male shows a dorsal crest. The word ' eft ' is sometimes applied to lizards and newts indiscriminately, and it may be useful to indicate some of the external differences between the amphibian newt and the reptilian lizard.

Newt (Amphibian)	Lizard (Reptile)
Naked skin.	*Scaly skin.*
No claws.	*Clawed digits.*
No ear-opening.	*Ear-opening.*
Tail slightly flattened.	*Tail cylindrical.*
Gills in the young stages.	*No gills.*
No foetal membranes.	*Two foetal membranes* (amnion *and* allantois)

Newts are terrestrial for most of the year, but prefer moist places. They often lie quiet in a hole in the winter months. In spring they

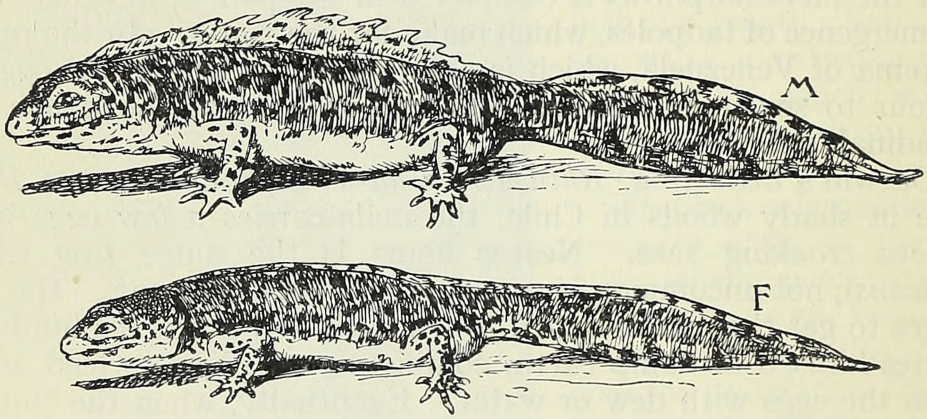


Fig. 190. Male (M) and Female (F) of the Crested Newt (*Triton cristatus*)

make for the water for breeding purposes, thus illustrating the usual return to the original habitat. There is a good deal of courting display and fondling on the male's part. There is no croaking. The eggs, which are *internally* fertilized, are fastened singly to pondweed and similar plants, and a leaf is sometimes folded over. After a fortnight or so the yellowish larva emerges from the egg-membrane and the gelatinous investment. It shows three pairs of external gills, and two pairs of thread-like outgrowths on each side of the upper jaw, which are used for anchoring to water-plants. The adult stage is usually reached by autumn, but some individuals remain as larvae till next spring.

Newts use the tail in swimming, the weak limbs in crawling. The

skin is very glandular, producing a secretion which is probably unpalatable; the skin is also very sensitive and there is a hint of the 'lateral line' of bony fishes. The outermost layer of the epidermis is moulted periodically, and the fingers are used in peeling it off and tucking it into the mouth!

The Alpine newt (*Triton alpinus*), not to be confused with the Alpine salamander (*Salamandra atra*), is found from the plains to a height of seven thousand feet. Very common in some parts of the United States is *Triton viridescens*, one of the more aquatic species. In the Iberian newt (*Triton waltli*) there is often a strange perforation of the skin by the pointed tips of the ribs. A good example of a lungless newt is *Desmognathus fuscus* of the eastern United States. One cave in Missouri is the home of the blind *Typhlotriton spelaeus*, whose eyes become covered over with skin at the time of the metamorphosis.

THE STORY OF THE AXOLOTL.—Allied to the newts is the genus *Amblystoma*, whose species are all American, except *Amblystoma persimile*, which inhabits, strange to say, the mountains of Siam and Upper Burmah. The commonest species is *Amblystoma tigrinum*, a dark-coloured, but spotted newt, six to nine inches in length, marked by its broad depressed head, wide mouth, long tail, stout limbs, golden eyes, and many other features, for it is a very characteristic animal. It is sometimes, but incorrectly, called a salamander (see below).

It is the larva that is called the axolotl, getting this name under the mistaken impression that it was different from the amblystoma. It may attain the adult's size, while still retaining larval features. It has three pairs of prominent branched gills, a compressed tail with a dorsal and ventral fin, slender limbs, and a narrower head than the amblystoma. The most remarkable feature, more or less cleared up about 1877 by Marie von Chauvin, is that the axolotl may remain a gilled form all its life, but may in this larval phase become reproductive and produce young ones. By varying the conditions of life it is possible to retain the axolotls as axolotls, or to turn them into amblystomas; yet the two forms may be found living together in the same lake.

This creature is probably the best instance of **neoteny** (*neos*, young; *teino*, stretch), which means an extension of the juvenile period beyond the usual limits and the setting in of reproduction. Neoteny occurs in some other newts, and without the onset of reproduction in many other forms. It shows that the normal **arcs on the life-curve** are capable of extension or contraction.

SALAMANDERS.—True salamanders, species of the genus *Salamandra*, are locally distributed in Europe and western Asia. A mist

of superstition used to surround them, for they were said to be able to live in the burning fire and to put it out when they chose. These beliefs are mostly dead, but the animals are more interesting than ever.

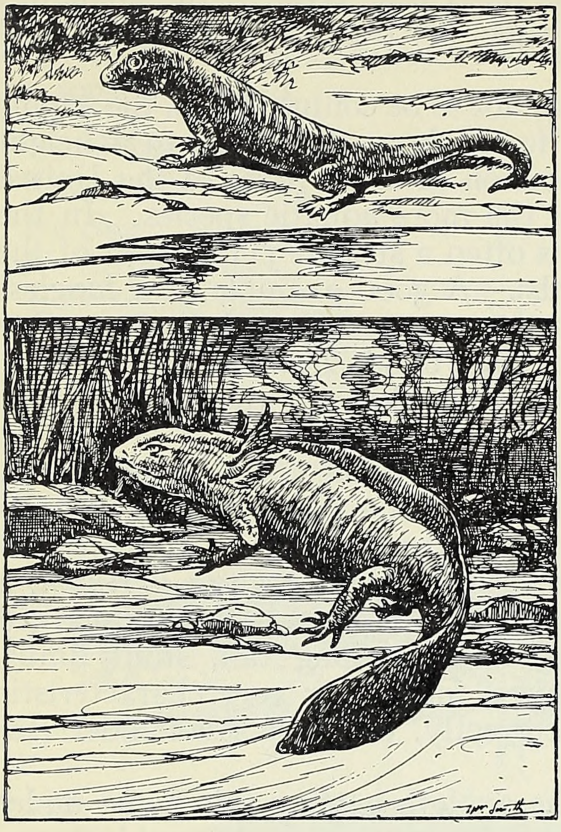


FIG. 191. THE 'SALAMANDER' *Amblystoma* (above) WITH ITS LARVA, THE AXOLOTL (below)

Thus the spotted salamander (*Salamandra maculosa*) shows the following points of interest and many more besides. The abundant skin-secretion, which is very irritating, e.g., if we touch our eyes or lips after handling a salamander, is doubtless protective, rendering the animal unpalatable. The yellow and black livery is very *variable* (i.e. changing according to the inheritance) and also very *modifiable* (i.e. changing according to outside influences). From October to April the salamanders disappear; they have buried themselves in the ground. The inch-long larvae, which are born viviparously in spring, are already about ten months old when they are set free, and the reproductive arrangements in general are peculiar. It is not surprising, then, that there should be remarkable *adaptations* in the related black salamander (*Salamandra atra*) of the Alps, to which we have already referred.

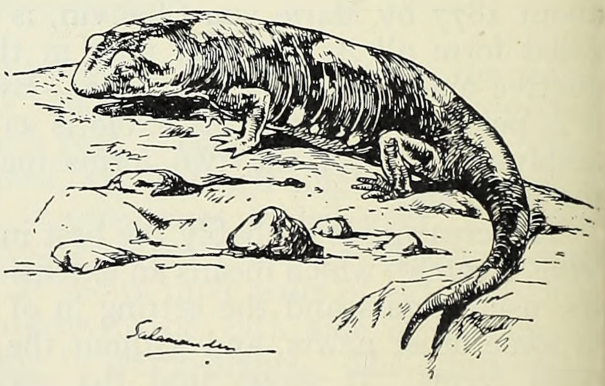


FIG. 192. A SALAMANDER

THE STORY OF PROTEUS.— The 'olm' or *Proteus*, found in some underground waters in Carinthia, Carniola, and Dalmatia, is one of those newt-like amphibians that retain the gills throughout life (*perennibranchiate*). It is about a foot long, with flesh-coloured skin, weak legs (with three fingers and two toes), an elongated and blunt head, hidden eyes which have suffered arrest of

development, and three pairs of tufted gills with the red blood shining through.

In its dark native haunts *Proteus* feeds on small crustaceans (e.g. *Niphargus*) and on little river-worms (like *Tubifex*); and captive specimens, in spite of their blindness, prove their ability to detect shreds of raw flesh held out to them in the water.

The eggs are fastened singly to the under-surface of projecting stones in the water, and each is towards half an inch in diameter, if the enveloping zone of jelly be included. The larva emerges after a slow development of about ninety days, and is about an inch long. If the development takes place in an ordinary well-lighted laboratory, the skin becomes dark instead of wan; but the eyes remain arrested on their way out from the brain, where all Vertebrate eyes begin. If the larvae are transferred from a cave to *red* light, the skin does not darken, but the influence of the red light, penetrating the *undarkened* skin, stimulates the arrested eye, which begins again to develop, reaches the skin, and actually becomes a seeing eye. Thus 'nurture' helps out hereditary 'nature.'

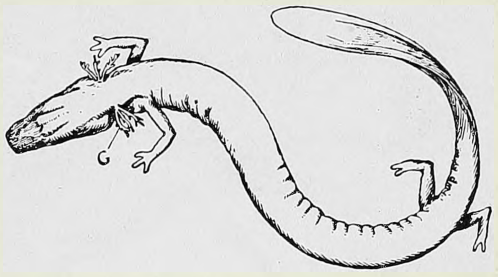


FIG. 193. *Proteus*
G, external gills.

Proteus has its counterpart in the little-known *Typhlomolge*, the Texas cave-newt. The two genera, so widely separated geographically, are yet so near one another in structure that they probably find a common ancestor in the mud-puppy, *Necturus*.

THE FROG'S YEAR.—The highest types among Amphibians are the frogs (*Ranidae*). They were the last notable types to appear on the stage but their pedigree is unknown. They have proved themselves very plastic and successful, taking to many diverse habitats and ways of living. We shall confine our attention here to a typical year's life—that of the common grass-frog (*Rana temporaria*).

The winter is spent in a comatose state, in a hole among moss, or in the mud near pools, or even under water. There the frog lies quiet—mouth shut, nostrils shut, eyes shut, with breathing movements suspended, with the heart beating feebly. It obtains the requisite oxygen through the skin (**cutaneous respiration**). Apart from oxygen it has no income, and apart from internal movements it has no expenditure. There is a gradual combustion of a reserve fatty tissue, called 'the fatty bodies.'

The reawakening is usually in March, but it varies with the outside temperature. It does not appear that the frogs are any the worse from their long fast. The males call to their mates, which cannot at first be

more than dimly sensed. The ' croaking ' of the males is truly vocal, being due to the passage of outbreathed air over the vocal cords in the larynx. We may call it the first voice or a distant repetition thereof. Its carrying power is increased by two internal resonating sacs that lie at the posterior corners of the mouth and bulge outwards when inflated. In the water-frog or edible frog (*Rana esculenta*), which is



Fig. 194. The Development of the Frog (*Rana*)

not a native of Britain, though often occurring as an escape, the croaking-sacs project very conspicuously when fully expanded. In our grass-frog the females have no croaking-sacs, and their voice is weak. There is considerable individuality in the voice of different species of frog; and there can be no doubt that we have here a hint as to its primary use—as a **sex-call.** After the breeding season is over, the male frog becomes as quiet as his mate. In higher forms of life the voice had other functions added to the sex-call; it became a filio-parental and parento-filial call, a kin-call, an expression of various non-sexual emotions, a means of conveying social information. Of course the sense of hearing had to keep pace with this, and the growing ' mind ' was a prime mover in the momentous evolution.

The common frog is not an animal that becomes very excited about things, but it wakes up a little at the breeding season. **Hormones** or chemical messengers are carried by the blood from the testes throughout the body, and one of the changes they bring about is the swelling and hardening of a pad on the male's first finger. This is used as a holdfast when the male grips the female in the coupling or embrace, which is sometimes so violent that the female is killed by it or drowned by prolonged immersion. Another change in the male is in the colour and



FIG. 195. THE EDIBLE FROG (*Rana esculenta*)

sheen of the skin, which sometimes has its counterpart in the female. On both sides there is probably some degree of emotional excitement.

As the male grasps the female she liberates the ova, sometimes two thousand altogether, and these are fertilized by the male's spermatozoa, which are shed upon the eggs just as these pass out into the water. In short, there is **external fertilization.**

The egg of the frog is about one-tenth of an inch in diameter, not including the much larger sphere of jelly. In the egg there is a considerable quantity of yolk, which sinks to the lower hemisphere; the upper one consists of deeply pigmented protoplasm. After fertilization has been effected, the **segmentation** or **cleavage** begins. It is just visible with the unaided eye—first, a vertical cleavage, dividing the egg into right and left daughter-cells; second, another vertical cleavage, at right angles to the first, dividing the egg into anterior and posterior halves; third, a horizontal or equatorial cut, dividing the egg into dorsal and ventral halves. This process of *total unequal* segmentation continues, and the result is a ball of cells. As these have

not as yet begun to grow, the size of the ball of cells, say at the 32-cell stage, is still one-tenth of an inch.

The three germinal layers are gradually defined—**ectoderm, mesoderm,** and **endoderm.** Division of labour sets in and the great Vertebrate events take place. That is to say, there is a formation of the dorsal nerve-cord, the supporting **notochord,** the muscle-segments, the primitive gut or **archenteron,** and the brain-eye. The body begins to take shape and moves by means of the tail within the gelatinous envelope. The minute algae and crustaceans—the 'flora and fauna' of the pond—help to loosen the jelly, and the hatching is not far off.

After Hatching. (1) About a fortnight after the individual life begins, that is at fertilization, hatching occurs. The larva breaks the delicate egg-membrane, escapes from the surrounding jelly, and swims in the water. What are its notable features? It is mouthless and limbless; with a ciliated ectoderm; with three pairs of protruding gills, borne by the first three gill-arches. On the under-surface of the head there is a glandular, crescent-shaped, adhesive organ that secretes a sticky slime. This serves to fix the larva at times to the water-weed, and the little creatures are often seen hanging on in rows.

Among the subsequent steps are the following: the opening of the mouth, which enables the larva to feed on algae and parts of water-weed; the opening of four pairs of gill-clefts from the pharynx to the exterior; the elongation of the intestine into a watch-spring-like coil; the change of the glandular crescent into two small disks, which gradually disappear as the power of caudal locomotion increases.

(2) A second period, the true tadpole stage, now begins. What are its features? A skin-fold or **operculum** grows over the external gills, forming a chamber. Within this chamber the gills dwindle away and are replaced by a second set, which are developed on the ventral halves of four gill-arches. These gills are usually called 'internal,' but it should be noted that they are, like their predecessors, covered with *ectoderm*, and not with endoderm as ordinary fish-gills are. They are comparable to the external gills of two of the mud-fishes, *Lepidosiren* and *Protopterus*, and of the bichir or *Polypterus*.

The mouth of the tadpole acquires horny jaws, and the fleshy lips bear horny papillae. By the continued growth of the opercular fold the gill-chambers have their opening reduced to a single pore on the left side. Through this aperture the water that is taken in by the mouth in respiration passes out again, having washed the gills on its way.

(3) The third period is marked by the appearance of the limbs as small buds. The two pairs start at the same time, but the fore-limbs take longer to get clear, being detained by the gill-cover. The hind-limbs may be watched in process of development, from small papillae to the complete limb.

The lungs begin to arise, as pouches from the gullet region, even before hatching; but they develop slowly, and it is not till the appearance of the hind-legs that they begin to function. This period is marked by a change in the behaviour of the tadpoles, which now rise to the surface of the water and take gulps of air. They are about two months old, and might be compared to the mud-fishes or *Dipnoi*, since they are

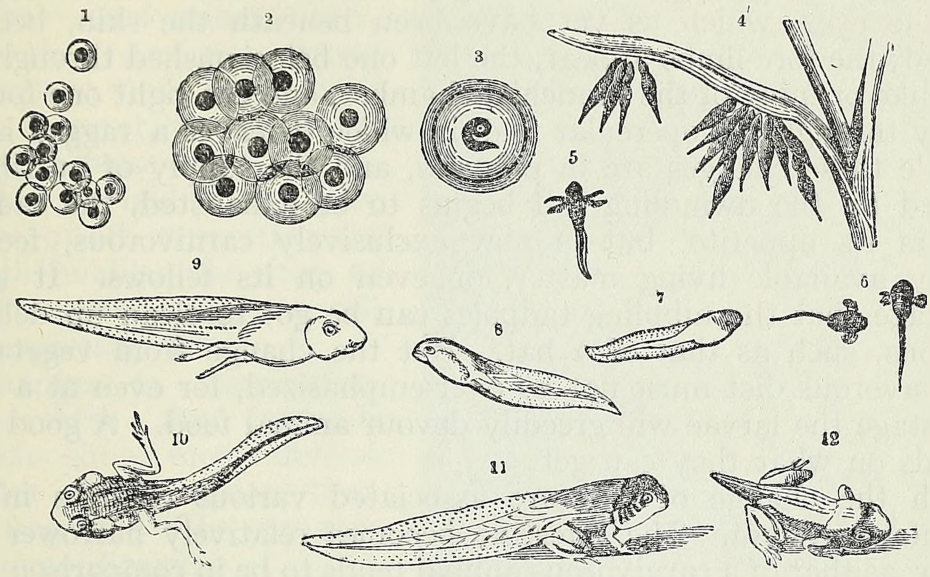


FIG. 196. DIAGRAM OF LIFE-HISTORY OF FROG.—After Brehm
1–3, developing ova; 4, newly hatched forms clinging to water-weed; 5, 6, stages with external gills; 7–10, tadpoles during emergence of limbs; 11, tadpole with both pairs of limbs apparent; 12, metamorphosis to frog.

breathing both by gills and by lungs. In an intricate way there is a change from a somewhat fish-like circulation to an amphibian circulation: thus the two-chambered heart of the period when the gills are the only functional breathing organs becomes a three-chambered heart; and the pulmonary circulation—involving blood-vessels to and from the lungs—is gradually established.

Metamorphosis. One of the first signs of the great change or metamorphosis is that the tadpoles lose their appetite for water-weed. The tail begins to be absorbed, in part at least with the help of wandering amoeboid cells or phagocytes which act as sappers and miners, breaking down the tail-tissues and transporting material towards the anterior end of the body. But there is also a degeneration of tissue, and liquefaction, so that fluid material can seep into the blood-stream. The gradual disappearance of the tadpole's tail is very much like a disease-process that has become part of the normal life-history, just as if pathological changes became regularized and useful. This is suggested

by some other phenomena among animals, such as the histolysis in the maggot when it is changing into a fly, or the eating away of the bone at the base of the stag's antlers before they fall off.

Some of the features in the metamorphosis are thus summed up by A. Milnes Marshall: 'The horny jaws are thrown off; the large frilled lips shrink up; the mouth loses its rounded suctorial form and becomes much wider; the tongue, previously small, increases considerably in size; the eyes, which as yet have been beneath the skin, become exposed; the fore-limbs appear, the left one being pushed through the spout-like opening of the branchial chamber, and the right one forcing its way through the opercular fold, in which it leaves a ragged hole.'

While these changes are in progress, and the supply of nutriment afforded by the dwindling tail begins to be exhausted, the tadpole recovers its appetite, but is now exclusively carnivorous, feeding on any available living matter, or even on its fellows. It is at this stage that the nibbling tadpoles can be got to clean up delicate skeletons, such as that of a bat. But the change from vegetarian to carnivorous diet must not be over-emphasized, for even at a very early stage the larvae will greedily devour animal food. A good deal depends on what they can get.

With the change of diet are associated various changes in the alimentary system. The intestine becomes relatively narrower and shorter, as that of a carnivorous animal tends to be in comparison with that of a vegetarian type. The stomach and liver enlarge. There is a continued absorption of the tail and a lengthening of the hind-legs. Eventually the tail is represented by no more than a short stump, and even that disappears. The aquatic swimming tadpole becomes a terrestrial jumping frog. As the metamorphosis is accomplished the young frogs must get out of the water which has so long cradled them. In an aquarium they are apt to be drowned at this stage unless some raft or shore is provided.

This life-history, from newly hatched tadpole to small frog, takes about three months. From one point of view it is to be thought of as a period of *relative* safety, for the chances of death for a weaponless, unarmoured little animal are far fewer in water than on dry land. From another point of view the individual life-history or development of the frog is a much-condensed **recapitulation** of the racial evolution of amphibians from a fish-ancestry. And yet this important point of view must be safeguarded by noting that the tadpole—without scales and with ectodermic gills — is amphibian and not piscine from the very start.

Let us dwell for a moment on this important point—*recapitulation and yet specificity*. When the tadpole is about a month old, it has a two-chambered heart, containing impure blood, which is driven to

the gills only, whence, purified, it passes to the body. All this is fish-like and illustrates **recapitulation.** Yet the gills of the tadpole are ectodermic, while those of an ordinary fish are endodermic, which illustrates **specificity.**

A fish has a non-muscular tongue; a frog has a very muscular tongue; recapitulation is illustrated by the fact that the tadpole's tongue is at first non-mobile. It has some muscle-fibres, but they are not strong enough to move it. Gradually, however, these muscle-fibres increase and the foundations are laid of the highly developed musculature which enables the frog to shoot out its tongue on the unsuspecting insect.



FIG. 197. A TOAD (*Bufo*) AND SPAWN

Changes in Respiration. Are there any animals which show more diverse modes of respiration than the frogs do? The sequence is extraordinary:

(1) *The newly hatched tadpole breathes cutaneously.*

(2) *Three pairs of projecting ectodermic gills develop.*

(3) *Gill-clefts open from the pharynx to the exterior.*

(4) *Inside the gill-chamber a second set of ectodermic gills replaces the first, which are absorbed.*

(5) *Gills and lungs are used at the same time, when the tadpole is about two months old.*

(6) *The small fully formed frog has lost all trace of gills and depends on its lungs, and partly on its skin.*

(7) *In winter the comatose frog is breathing by its skin only—cutaneous respiration.*

Changes in Nutrition. Very striking is the sequence in the modes of nutrition. The newly hatched mouthless larva is dependent on the remains of the yolk material in the egg; the first actual food consists typically of algae and pieces of water-weed; after a period

of fasting there is the metamorphosis, in which some of the degenerated tail-tissues afford a nutritive supply; then follows a carnivorous period, occasionally cannibalistic; the full-grown frog is mainly insectivorous.

Life in the Fields. While the new generation of tadpoles is developing in the relatively safe cradle of the water, their parents have been living dangerously in the fields, to which they betake themselves in April. The adults are followed in June or July by the froglings of the year, which migrate from the pools or ponds in great numbers. They sometimes form the basis of stories of 'frog-showers,' but this phenomenon may also be due to cyclones which carry up the metamorphosing larvae in whirling columns of water. The migrating young frogs are well under half an inch in length—much shorter than the full-grown tadpoles.

In the fields and meadows the young frogs feed on small insects, slugs, and the like, and grow slowly larger. Every now and then their slow growth is punctuated by a moult. That is to say, the outermost layer of the epidermis, often much the worse for wear, is split up along the mid-line of the back and slipped off. It is usually swallowed.

The small frogs, though far from conspicuous, are picked up by birds, stoats, grass-snakes, and other enemies, so that there is only a remnant to make the return journey towards the ponds. This occurs in autumn, when food is becoming scarce. They are now about three-quarters of an inch long. Somewhere near the pools, or even in the mud under the water, they pass into the winter lethargy from which we started.

Blindworms

The upward path of Organic Evolution is very zigzag, like a road up a steep ascent. That zigzagness is not so difficult to understand as the occurrence of numerous by-ways that seem to lead nowhere, or, in some cases, to turn downhill again. Nature is like an artist with an affection for his tentative sketches; he cannot bear that they should be cast 'as rubbish to the void.' We can understand, however, that in the course of ages many masterpieces have had to go—some too daring, others unable to stand the weather; but what often amazes us is the survival of weird creatures that live the queerest of lives in the nooks and crannies and out-of-the-way corners of earth and sea.

We suppose that the fact of the matter is the organism's unwillingness to say die. Some exquisite creatures are readily discouraged, and many, like the delicate *Graptolites* at one pole and the flying dragons or *Pterodactyls* at the other, disappeared from the stage millions of years ago *without leaving any successors*. They emerged, they prospered, they had their Golden Age, they began to dwindle in numbers,

and they entirely disappeared. We suppose they must have left some mark in history, but when they dwindled away the System of Animate Nature was, so far as we can see, as though they had never been. Especially in later days when man has interfered, there have been many disappearances, often dramatically sudden, as in the case of the passenger pigeon and the great auk, the quagga, and Steller's sea-cow. But what we are concerned with just now are tough creatures that refuse to be conquered. They are ' die-hards ' indeed, living penuriously in hidden ways and obscure circumstances, **cryptozoic refugees** that will not admit defeat. Among these ' die-hards ' must be ranked the blindworms—limbless, earthworm-like amphibians that have taken to a subterranean life.

The blindworms (*Caecilia*) are not to be confused with slow-worms, which are limbless lizards, innocent and interesting creatures, such as the *Anguis fragilis*, not uncommon on some British moors and grassy places. It is not merely that the slow-worm has perfectly well-developed eyes, but it is a *reptile* through and through, whereas the blindworms are amphibians. The resemblance is a purely superficial **convergence**, due to similar adaptations to similar conditions of life. It often puzzles a student to distinguish, by external inspection, between a blindworm, a slow-worm, and a burrowing snake; but there is no difficulty at all when the internal organs are looked at.

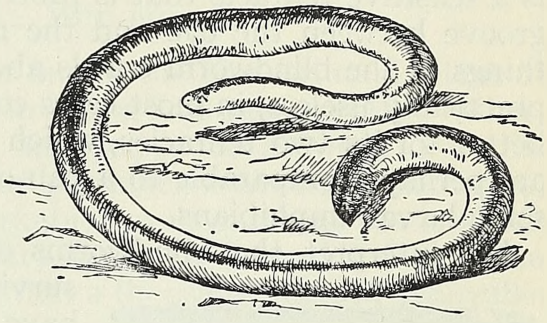


FIG. 198. A BLINDWORM (*Caecilia*)

Blindworms are restricted to Central and South America, tropical Africa, India, Siam, and Malay. No fossil forms are known, but the structure of the living animals shows that they are extremely ancient. They are antediluvian antiques who have kept going by taking refuge in the underworld. Externally they are suggestive of big earthworms, but they are of course backboned. Yet they have no limbs, no girdles, no breastbone. They may be at once distinguished from snakes and limbless lizards by the smooth and slimy skin, which betrays the amphibian. Yet it must be noticed that this skin shows superficial rings which are just a little suggestive of transverse rows of scales. Moreover, there is this complication, that in many kinds of blindworms there are small, partly calcareous scales deeply embedded in the under-skin. These scales are quite different from the epidermic scales of Reptiles, and are usually regarded as a legacy from the extinct *Stegocephali* or *Labyrinthodonts*, which formed the most primitive order of Amphibians. It was characteristic of these very ancient

Amphibians that they had an abundant armature in their under-skin; and the Caecilians of to-day come nearer to these pioneers than do any other living Amphibians, such as frogs and toads, newts and salamanders. It cannot be supposed that the tiny scales of blindworms have much protective value; they are **relics,** and there is probably more utilitarian significance in the slime secreted in the skin, for it may be unpalatable or poisonous. Handling fresh specimens brings on sneezing, and this may be symptomatic of something irritant which might have protective value in the struggle for existence.

Blindworms swarm with old-fashioned characters. Thus the vertebrae, which may be 275 (!) in number, have the double-egg-cup shape that is characteristic of most fishes; and they bear strong ribs, which is not the case with ordinary amphibians. A strange structure is a sensitive tentacle that is protruded by an ingush of blood from a groove between the eye and the nose. It seems to be used to test things as the blindworm crawls about. The eyes are degenerate and practically useless, in most cases covered over. So the creature is the better for its two tentacles, which are nothing if not peculiar. They are perhaps comparable to a pair of **balancers** which are to be seen in some larval amphibians.

We interpret the blindworms or *Caecilians* as gentle, inoffensive survivors of an ancient fauna, which have persisted by becoming burrowers; and to this mode of life they are adapted in the worm-like elongation of the limbless body (an elongation which the study of the embryonic development shows to be *secondary*), in the annulation of the surface, in the extreme shortness of the tail, in the hiding away of the eyes, and so forth. In internal adaptation to the lengthening-out of the body, the left lung has dwindled to a minute vestige, and the liver is much elongated. So the quaint creatures are still bundles of fitnesses, and seem to be holding their own in suitable places. About forty different kinds are known.

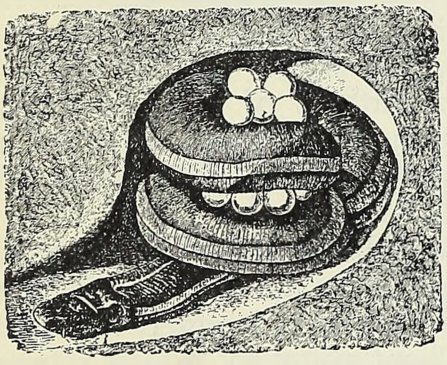


FIG. 199. A CAECILIAN (*Ichthyophis*), WITH EGGS.—After Sarasin

Some Caecilians lay eggs, while others are viviparous; but in all known cases the eggs are relatively large and the early development is quite unlike that of frogs and newts. Two oviparous forms, *Ichthyophis* and *Hypogeophis*, have been carefully studied, and in both cases the mother liberates the eggs in holes in the damp earth, and coils herself round them. In both cases there are in the embryos three pairs of external gills, just as in a very young tadpole, but they disappear

before hatching—an extraordinary instance of individual recapitulation of racial history, and yet of marked change at the same time. In *Ichthyophis* from Ceylon the newly hatched young one makes for the water, but as it has discarded its gills, it has to come to the surface to gulp air. It has gills before it is hatched; it has persistent gill-clefts in the water, possibly of some use, but it is a lung-breather from the day it leaves the egg. Eventually it takes to burrowing on land. In *Hypogeophis* from the Seychelles the aquatic stage is skipped, and the gill-clefts are closed before hatching. What anti-evolutionists make of such facts we do not know. To the evolutionist they are luminous, and so we are intellectually grateful to these archaic, cryptozoic blindworms.

The Ancestral Mud-puppy

We wish to linger for a little over one of the pioneer amphibians of long ago. One might be well versed in geology, or palaeontology rather, without knowing much about the mud-puppy or *Eryops*. Yet this extinct type has suddenly sprung into prominence as one of the heroes, so to speak, of one of the most remarkable novels of recent years, which is saying a good deal—we mean Mary Borden's *Jehovah's Day*. The title is in reference to the fine saying that a thousand years in Jehovah's sight may be as one day.

Why should the artist single out *Eryops* from amid the crowded ranks of bygone animals, and do it an honour to which no other fossil, so far as we are aware, has ever attained? The answer in brief is that Eryops was among backboned animals one of the pioneers of terrestrial life. It was a leader in the momentous Vertebrate invasion or colonization of the dry land—an advance that was the beginning of a new era. Leaving the water and getting on to terra firma was a great step towards the higher life of animals. For the mud-puppy was one of the first of the Reptiles, whence arose Birds and Mammals. From his loins sprang a promising progeny, including, after hundreds of millions of years, our noble selves. Mud-puppies were not much to look at, but they were justified of their children. If it had not been for the mud-puppy this book would not have been written!

The mud-puppies (*Eryops*) used to be regarded as Amphibians, but they are now classified as *Proreptilia*. This matters little, for the boundary is vague between some of the ancient armoured Amphibians, called *Stegocephali*, and the most generalized of the extinct Reptiles. The skeletons of these ancestors of the mud-puppy are found in Carboniferous strata, but there are eloquent footprints of earlier date, namely in the Devonian. We say ' eloquent ' since they are the first tracks of creatures with fingers and toes—a great acquisition in the

history of animal life. The mud-puppies themselves belong to Permian times, and their strongly developed limbs and girdles point to well-established terrestrial habits. Like their Stegocephalous forbears they were armoured, but only on the under-surface.

There is nothing nebulous about the fossil skeletons of the mud-puppy that are found in Texas and New Mexico. The strong skull is broad and flat, about eighteen inches in length and twelve in breadth; there are numerous small and pointed teeth, probably suited for crunching insects; the limbs are strong and the tail is short. So we might continue, but for our present purpose unnecessarily. For while the comparative anatomist must know all he can about Eryops, even such a detail as the absence of a second finger, the general evolutionist need only know that there are remains of very old-fashioned quadrupeds, half-amphibian and half-reptilian, which were pioneers in the colonization of dry land by backboned animals.

'He was an ugly brute, a giant tadpole four feet long, small-brained and slow, with a wide flat head, no forehead, chin, or neck, but with a thick heavy body, four short legs, and a weighty flattened tail. The faint noise of his great feet and scaly tail scraping the muddy bank sounded across the hush of the dreaming unpeopled earth like thunder, travelled up and out past stars and suns and moons to the particular centre which noticed this sort of thing, and signalled quickly, precisely as a ticking telegraph, the news that the first backboned adventurer on the tiny spinning earth had set out to explore the dry land.'

More clearly than many palaeontologists, too often overloaded with learning, Miss Borden has realized that something explosive happened that misty morning a hundred or more million years ago when the grotesque mud-puppy lifted his flat head out of the shallow water of an inland sea and began to climb up the bank into the swampy flowerless forest with its seductive whiffs of scent. 'He was one of the first living creatures to possess fingers and toes to feel with, ears to hear with, vocal cords to speak with, and a three-chambered heart that pumped pure blood to his brain.' Urged by curiosity and by a deep discontent with his surroundings, he began to explore. As a matter of fact he began to catch spiders. 'He felt suddenly a wild exultance, and, opening his mouth wide, he called to his mate to come and join him, and the first voice sounded at that instant on the earth.'

To some temperaments this may sound anthropomorphic, yet is it not nearer the truth than mechanomorphic aetiology that leaves out of account the part that living creatures have played in their own evolution? They have urges and impulses, which we have no right to try to cover with the word 'gastric,' to which we have no right to deny a mental aspect. Mind was more than nascent in the mud-puppy. 'The Cosmos took note of the fact that a voice had broken

its rhythm, and that an individual creature had performed an act of daring '—something more than a reflex gulp from its muddy bed at a dragon-fly planing past.

The artist's daring use of the mud-puppy, as of other fossils to which

A



B

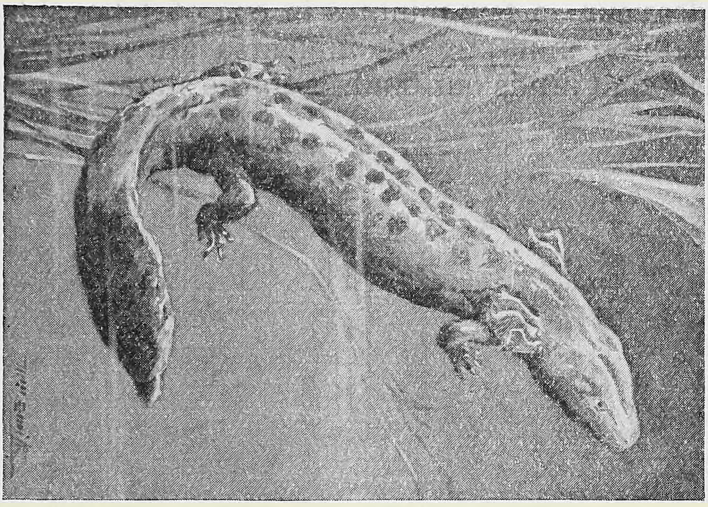


FIG. 200. TWO INTERESTING AMPHIBIANS
A. The flying frog of Java (*Rhacophorus pardalis*).
B. A giant newt.

she has given life, is to provide *a scale of time.* Suppose there were made, as we have elsewhere suggested, the second grandest film of mundane occurrences, namely the sequence of **Organic Evolution.** Suppose there was allotted to each geological period a proportionate length of film, on which were depicted the plants and animals, the scenery and climate of the time. Suppose the film began to be unrolled before dawn at such a rate that it would finish by midnight,

when would man appear on the moving stage? He certainly would not appear before 11.45 p.m.!

Some experts estimate that *Eryops* emerged one hundred million years ago, while others would say three hundred. This is a sobering thought, and the precise number of millions matters little if we get the proportions right. Thus, if the mud-puppy appeared at dawn on one of Jehovah's days, the first bird took the air at noon, and man arrived on the scene in the evening. 'By evening human beings were exploring with telescopes the island universes of the starry firmament, and were peeping over the edge of a spiritual world, as yet only dimly apprehended.'

The astronomers have shown that man inhabits a small satellite of a mediocre star journeying in a little corner of one of the many universes; yet this man has measured the world, formulated much of its orderliness, outlined its history, and brought many of its forces into his service.

Similarly, if tentative men began to emerge between one and two million years ago, whereas living creatures date from some time nearer a thousand millions, how exiguous has been the whole duration of human endeavour—a few minutes in one of Jehovah's days! Yet we believe that the mud-puppy's millennia are justified by a single human moment that sends out tendrils to the stars.

CHAPTER XIX

REPTILES

Living and extinct Reptiles—Acquisitions made by Reptiles—Sub-classes of Reptiles—General characters of Reptiles—Some notable Reptiles.

LAND-TORTOISES and water-turtles, all the many kinds of lizards and the unique New Zealand 'lizard' besides, the hundreds of snakes or serpents, and the giant crocodilians: these are the reptiles of to-day. But account must also be taken of some sub-classes or orders of extinct reptiles, like the fish-lizards (or *Ichthyosaurs*), the land-dragons (or *Dinosaurs*), and the flying-dragons (or *Pterodactyls*). All these and many more are long since gone, but a distinction must be made between orders like the *Pseudosuchians* and *Therapsids* which have Birds and Mammals as their *indirect* descendants, and orders like the *Pterodactyls* which have no living descendants at all. Both these cases must be distinguished from, let us say, fossil crocodilians which have the crocodiles and alligators and gavials of to-day as their *direct* descendants.

ACQUISITIONS OF REPTILES

REPTILES POSSESSED THE DRY LAND.—In the history of backboned animals the colonization of the dry land was begun by Amphibians, if we leave out of account certain adventurous fishes. But, as we have noted, the Amphibians have for the most part to return to the water to spawn, and they have in most cases to pass through a gill-breathing aquatic stage, familiar in the tadpoles of frogs and toads. What the Amphibians began was carried further by the Reptiles, for they became quite independent of the water, and they never have any gill-breathing stage. Before the young reptile is born from the mother or hatched from the laid egg it breathes through blood-vessels which are spread out on a birth-robe, called *allantois*, from a Greek word meaning 'sausage.'

FOETAL MEMBRANES OR BIRTH-ROBES.—The *allantois* may be defined as a sac that grows out, in Reptiles, Birds, and Mammals, from the hind end of the embryonic food-canal and expands outside the embryo, spreading out blood-vessels so that oxygen is captured and carbon dioxide is got rid of. In reptiles and birds the exchange of

gases takes place through the egg-shell (which is soft in some reptiles); in mammals the allantois forms part of the **placenta** (q.v.), and the exchange of gases takes place between the blood-vessels of the mother and those of the embryo that are spread out on the allantois. Besides being respiratory, the allantois of reptiles and birds sometimes absorbs white of egg, and it may also serve as a temporary receptacle for the nitrogenous waste-products of the embryo. Thus an allantois of reptile or bird may have three functions: *respiratory*, *nutritive*, and *excretory*; and it has still these three uses when it forms part of the placenta in mammals. The unborn or unhatched offspring of a higher animal is sometimes called a **foetus**, especially in mammals, and thus the term *foetal membrane* is applied to the allantois and also to a protective membranous hood called the *amnion*.

The **amnion** is a membranous fold developed in reptiles, birds, and mammals around the embryo, and forming in part a protective dome containing fluid. This amniotic fluid bathes the embryo, and the water-bag arrangement thus formed protects the delicate young life from injury when the eggs are moved about, or when the mother, carrying the young, has a bad tumble or has to jump for her life. Both the amnion and the allantois are lost at birth or at hatching, but the internal stalk of the allantois becomes the bladder of the animal, if it has one; and here it may be noticed that the peculiar bladder of amphibians, e.g. the frog, corresponds in development to the allantois of reptiles, birds, and mammals. To the lower Vertebrates (Fishes and Amphibians), which have no hint of an amnion, the technical term **Anamnia** (*an*, without; without an amnion) is applied; the higher classes (Reptiles, Birds, and Mammals) are similarly called **Amniota** (i.e. with an amnion).

Reptiles are to be thought of, then, as the first backboned animals to *possess* the dry land; and this difficult subject of birth-robes is to be thought of in connection with the new departure of being born or hatched quite away from the cradle of the water. Gills, which are suited for breathing in water, had to be discarded on dry land, and a new way of breathing in the days before birth had to be discovered. The discovery was the allantois that we have been discussing — a birth-robe that could capture oxygen during the period of development, while the lungs were still in process of being formed. For all reptiles become lung-breathers, just like ourselves.

SOME REPTILES RETURNED TO THE WATER.—It may seem for a moment strange to speak of reptiles as possessing the dry land, when every one knows of turtles and sea-snakes swimming many miles from the coasts, of water-tortoises in the ponds, of crocodiles in the river, and so on. This is a very interesting point, for all these aquatic reptiles have *gone back* to the water. They have turned back from

the trail which their ancestors blazed and become aquatic once more. But the hands of the evolution clock cannot be turned back, and lung-breathers cannot become gill-breathers again. Thus all these *secondarily aquatic* reptiles have to come to the surface to breathe dry air with their lungs; and they have to return to dry land to lay their eggs. For the eggs of an animal that has entirely lost gills could not develop in sea or pond or river; and it would be very difficult for a lung-breathing young animal to escape drowning if it were born in the water. Very difficult, we say, but not impossible, for the whales have solved the problem which has baffled the reptiles.

When a race of animals has changed its haunt, the rule is that the young stages are passed through in the ancestral home. The loggerhead turtle has become an Open-Sea reptile, but it has to go back to the sandy beach, of Florida for instance, to lay its eggs; and the young ones are hatched out of the egg after breathing for a long time through the allantois spread out inside the shell. The land-crabs go up the hills and the robber-crabs climb the coco trees, but they have to go back to the sea to spawn, and the young ones have to sojourn there for a long time. The life begins afresh in the old home.

OVIPAROUS AND VIVIPAROUS.—These are not very happy words, but we cannot get rid of them now. As all backboned animals develop from eggs, all are in a strict sense egg-bearing or oviparous; but what the term means is that *the eggs hatch outside of the body*. As offspring must be alive when they are produced, unless some accident has occurred, all animals may be said to be in a strict sense viviparous, but the word means that what is liberated from the mother is a young creature which has been developing for some time within the mother, sometimes in close partnership with her, and has reached before birth a considerable degree of likeness to the full-grown form. In ordinary mammals there is a close and often prolonged partnership between the mother and the unborn young by means of the placenta (see INDEX), and what is born is more or less a miniature of the adult, and this is the best illustration of what is meant by **viviparity,** to use the noun made from the adjective. But in most of the hound-sharks (*Mustelus*) and in the blue-sharks (*Carcharias*) the unborn fish is nourished by an attachment to the wall of the mother's oviduct; and there are other cases, outside of mammals, where the young are in some measure nourished from the mother before birth. This is true of the two well-advanced young ones that are born from the black salamander of the Alps; and there is some food-absorption, apart of course from the yolk of the egg, in a few reptiles. In a general way, then, we say that an animal is viviparous when the young one leaves the mother more or less fully formed in its general features, and we use

the word more particularly when there has been before birth some partnership between mother and offspring.

In the sense just explained, seed-bearing plants are viviparous, and the term is even more justifiable when the seed has begun to sprout before it leaves the parent plant, as in some of the mangrove trees. In one of these the part of the young shoot below the seed-leaves (the *hypocotyl*) has actually attained a length of eighteen inches before the seed falls from the parent. It seems a pity that the word ' viviparous ' should be applied to various plants that develop separable buds or even young plants on their leaves or other parts, as in the cuckoo-flower, the begonia, the sheep's fescue, and, best example of all, the *Bryophyllum*, one of the house-leek family. This is a kind of vegetative or asexual multiplication, and rather different from what we are now considering.

In some sharks, a few bony fishes, some tailed amphibians, a few lizards and snakes, the young are hatched out of the egg just before or shortly before they leave the body of the mother. To this state of affairs the awkward term *ovo-viviparous* is applied—the worst of the three words. There is very little difference between oviparous and ovo-viviparous birth, and both may occur in one and the same animal at different times or conditions, as in the grass-snake. Some eggs require to develop for a long time before they are ready to hatch out; some are ready in a very short time; some are hatched just as they are liberated; and others shortly before. So it is all a question of degree. Let us sum up for backboned animals in general:

Oviparous.

MOST FISHES.
MOST AMPHIBIANS.
MOST REPTILES.
ALL BIRDS.
DUCKMOLE AND SPINY ANT-EATER.

Ovo-viviparous.

In SLOW-WORMS the eggs hatch immediately after they are laid; so also in the VIVIPAROUS LIZARD and the DWARF CHAMAELEON.

Viviparous.

WITH NO NUTRITION EXCEPT FROM YOLK, e.g. viviparous blenny and adder.

WITH SOME FOOD-ABSORPTION APART FROM YOLK, e.g. some dogfishes, the torpedo, the black salamander, a few reptiles.

WITH A HINT OF A PLACENTAL UNION, hound-shark and blue-shark.

AFTER PLACENTAL PARTNERSHIP, all ordinary mammals.

Sub-Classes of Reptiles

(*a*) **With living representatives.**

Tortoises and Turtles:	**Chelonia.**
Crocodiles, Alligators, Gavials:	**Crocodilia.**
Snakes or Serpents:	**Ophidia.**
Lizards:	**Lacertilia.**
New Zealand 'Lizard,' *Sphenodon* or *Hatteria*:	**Rhynchocephalia.**

(*b*) **Extinct.**

Land-dragons or **Dinosaurs**; Fish-lizards or **Ichthyosaurs**; Flying-dragons or **Pterodactyls**; swan-neck Reptiles or **Plesiosaurs**; and other sub-classes.

GENERAL CHARACTERS OF REPTILES.—(1) Reptiles have horny **scales,** made out of part of the outer skin or epidermis. As long as they are growing they are nourished by the under-skin or dermis, in which there are blood-vessels. Moulting in reptiles means a periodic shedding of the outermost layer of the epidermis, which has ceased to have any life in it. In various reptiles, such as crocodiles, there are bony plates (called **scutes**) developed in the dermis below some of the epidermic horny scales. The skin is poorly provided with glands.

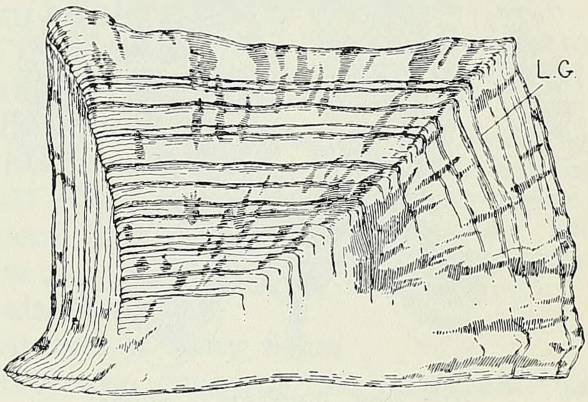


Fig. 201. Scale of Tortoise (*Testudo*)
LG, line of growth.

(2) Reptiles are typically four-footed animals with **clawed digits,** but snakes are limbless and so are some lizards. When the limbs have been turned into flippers, as has happened in turtles, the claws have disappeared.

(3) Reptiles are **lung-breathers,** and gills are entirely absent. In the embryo there are always gill-clefts (just as in embryo-birds and embryo-mammals), but these are vestiges of the reptile's distant aquatic ancestry, and are of no use in respiration. They are short-lived structures except the first one, which forms (as in ourselves) a connection between the outer ear-passage and the back of the mouth (called the **Eustachian tube**). These vanishing gill-clefts are good examples of 'historical relics,' showing us how the past still lives in the present; and it is very interesting that at least one case is known of a reptilian embryo showing minute tags in its gill-slits, which must be the last traces of gills. It will be understood that gill-slits or gill-clefts are

openings from the beginning of the food-canal (the pharynx) to the outside, whereas **gills** are feathery structures bordering the clefts. So we may say that while the Amphibians are the highest animals that have *gills*, the embryos of Reptiles, Birds, and Mammals have **gill-clefts,** one of them persisting in adult life.

(4) The embryo reptile has two **foetal membranes** (q.v.)—which a beginner may perhaps call **birth-robes**—the **amnion** and the **allantois.** (See ACQUISITIONS OF REPTILES.)

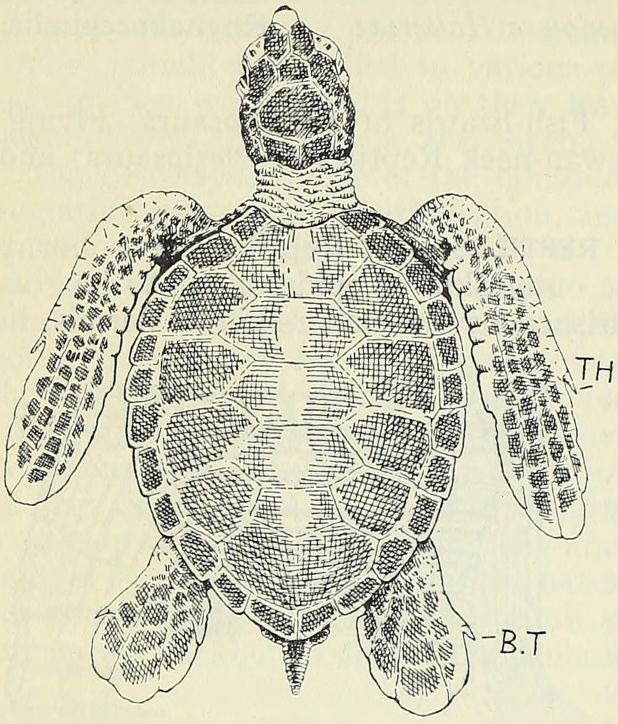


FIG. 202. TURTLE (*Chelone*)
TH, thumb; BT, big toe or first digit.

(5) Another general character that links Reptiles to Amphibians and Fishes (*Ichthyopsida*) and separates them from Birds and Mammals is **cold - bloodedness.** That means, to repeat a little, that they tend to approximate in body-temperature to the temperature of their surroundings. A snake basking on the sand under a tropical sun has a high body-temperature, but another lying on the path across a moor in the north of Scotland has a much lower temperature. One and the same reptile may have very different temperatures in different conditions, whereas birds and mammals have an almost constant temperature, year in and year out, night and day. In other words, birds and mammals have a physiological arrangement (**thermotaxis**), by which they adjust their production of bodily heat (chiefly from the muscles) to their loss of it to the outer world (see ANIMAL HEAT).

The great advantage of warm-bloodedness is that uniformity at a comparatively high temperature allows the chemical routine of the body to go on quickly and smoothly. Correspondingly, the handicap of cold-bloodedness is that it tends to keep the bodily routine or metabolism at a relatively low level of intensity. Thus most reptiles are very slow-going and lethargic as compared with most birds and mammals.

(6) The **heart** is in most cases three-chambered, in this respect like that of an amphibian, but in the crocodilian reptiles the heart is four-chambered, like that of birds and mammals. In the ordinary reptile the heart has two receiving chambers or **auricles,** the right for

impure blood from the body, and the left for pure blood from the lungs, just as in ourselves. But there is, except in crocodilians, only one driving chamber or **ventricle**, which must therefore contain both pure and impure blood. This ventricle is incompletely divided, by a partition or septum, into a right half with impure blood and a left half with pure blood, so that the two kinds of blood do not mingle so much as one might expect. In crocodiles and their relatives this partition or septum is completed, so that the heart is four-chambered.

(7) In front of the driving chamber or ventricle of the frog's heart there is a muscular continuation with valves, called the **conus arteriosus**, and from this there arise three pairs of arteries or **aortic arches** —the carotids to the head, the systemics to the posterior body (uniting to form the great **dorsal aorta**), and the pulmonary to the lungs and skin. If we turn from the frog's heart to that of a reptile, like the tortoise or turtle, we see the three aortic arches arising directly from the heart, with valves at their origin, but *no conus*. This is an important anatomical difference. It may be mentioned here that skates and other *Selachians* show a very well-developed conus; this is also true of the mud-fishes or *Dipnoi*, but not of bony fishes.

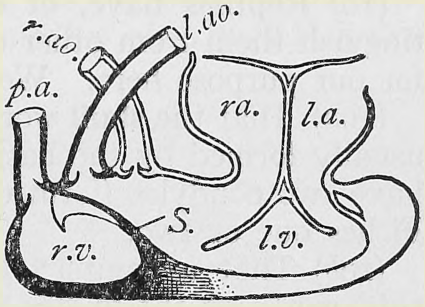


FIG. 203. DISSECTION OF HEART OF TURTLE (diagrammatic). —After Huxley

rv, right half of ventricle; *s*, septum; *lv*, left half of ventricle; *ra*, right auricle; *la*, left auricle; *l.ao*, left aortic arch; *r.ao*, right aortic arch; *pa*, pulmonary arch.

(8) Another important difference also concerns the heart and its blood-vessels. The **dorsal aorta** or main artery, which gives off branches supplying the whole posterior body, is formed, as in Amphibians, from the union of two systemic arches. One of these, from the right half of the ventricle, and therefore with impure blood, bends over to the left side; the other, from the left half of the ventricle, and therefore with pure blood, bends over to the right side; they unite to form the dorsal aorta, so that most of the posterior body is supplied with **mixed blood.** It is the same in crocodilians, though in this subclass we must speak of the right and left ventricles, not of the halves of one ventricle.

But when we turn to Birds and Mammals what do we find? We find that the dorsal aorta is formed by one aortic arch, issuing from the left ventricle and therefore containing pure blood only. That the aortic trunk bends to the right in birds, to the left in mammals, is not the point; the important fact is that the dorsal aorta is formed from a single aortic arch, arising from the left ventricle, and *with pure blood only*.

(9) In Reptiles the **red blood corpuscles** are nucleated, biconvex, and oval in outline, much the same as those of Fishes, Amphibians, and Birds. But they are very different from those of Mammals, which are non-nucleated (when definitely formed), biconcave, and circular in outline (except in *Camelidae*, where they are oval). In Reptiles the **white blood corpuscles** are like those in other Vertebrates, viz. somewhat amoeboid nucleated cells, showing considerable diversity in detailed structure.

(10) Reptiles have, of course, various **skeletal features** that distinguish them from other classes, but most of these are too technical for our purpose here. We may notice, however:

(10*a*) That the **skull** works on the first vertebra by a single **condyle,** usually formed by the basi-occipital bone; Amphibians and Mammals have two condyles (formed from ex-occipital bones); Birds have one; Fishes one or two.

(10*b*) That a complex **lower jaw,** sometimes of six bones on each side, works on the quadrate bone, as is also the case in Birds, whereas in Mammals a simple lower jaw works on the squamosal.

(10*c*) That a single lever, the **columella,** conveys the vibrations produced by sound-waves to the inner ear, as is also the case in Amphibians and Birds, whereas in Mammals the same function is performed by a three-link chain of minute ossicles.

(10*d*) There is often a true breastbone or **sternum**, as in Birds and Mammals, formed from a coalescence of the ventral ends of ribs.

(11) There is always a typical **cloaca,** i.e. a common chamber (with one opening) which receives the end of the food-canal, a ureter from each kidney, and the genital ducts. A cloaca is also characteristic of cartilaginous Fishes like skates and sharks, of Amphibians like frogs and newts, of Birds, and of the two or three egg-laying Mammals.

(12) The **eggs** are relatively large, with much yolk, and exhibit partial discoidal segmentation. There is internal fertilization before the shell is formed; and

(12*a*) **Insemination** is effected by means of a male copulatory organ or **penis,** which passes from the cloaca of the male into that of the female, with the single exception of *Sphenodon,* the New Zealand 'lizard.'

Some Notable Reptiles

CROCODILES.—One of the few drawbacks to living in Britain is that we cannot see crocodiles 'making the deep boil like a pot and stirring the sea like ointment.' Of course they don't live in the sea, but we must give the poet his licence. But how can we be expected to see life whole if we cannot look upon a crocodile at least once a

year? He was the old Leviathan, whose praises are sung in the Book of Job:

There is not his like upon earth,
Created to know no fear.
Everything that is high is afraid of him ;
He is king o'er the sons of pride.

The crocodile is an antique, going back to the Upper Crustaceous Ages, and back to the Upper Jurassic if we use the word crocodilian. Further back still we lose the race amid a medley of extinct Reptiles. Thus we prize the crocodiles of to-day, for they are the survivors of an ancient stock that began many millions of years ago. Most of the different kinds have long since become extinct, but six genera are left, relics of the Age of Reptiles. We suppose that the disappearance of the others must have been mainly due to changes of the earth's surface, such as elevations that were followed by aridity, for crocodiles do not look as if they were likely to suffer either from enemies or from the biting of Time's tooth.

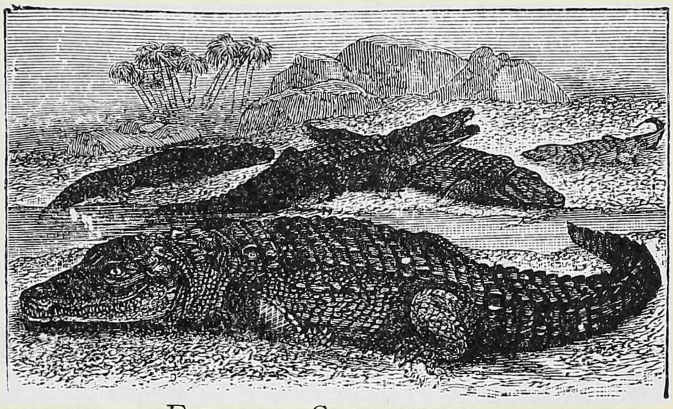


FIG. 204. CROCODILES

The flakes of his flesh are welded
So firm that they cannot be moved,
His heart is as firm as a stone—
Yea, firm as the nether mill-stone.

The crocodile is unique. There is no animal in the world that one could confuse it with, except perhaps an alligator, and an alligator is a kind of crocodile. A generation ago the medical student used to be ' spun ' who could not tell the differences between a crocodile and an alligator, but these good old days are past. What, however, are the characteristics whose combination makes the crocodile unique? There is the fine armour, for instance, which includes, besides the horny epidermic **scales,** a deeper dermic series of body **scutes** which are almost confined to the dorsal surface. We suppose that the crocodile's skin of commerce is the under-skin or dermis without either the scutes or the scales. Each scale shows a little pit in which a nerve ends, so that the heavily armoured leviathan must not be thought of as callous. How well his suit fits him: *His scales are his*

pride, shut up together as with a close seal. And how strong the ventral scales are that leave their marks on the mud:

Under him he hath sharp potsherds,
He spreadeth a threshing-sledge on the mire.

But as armour suggests weapons, so the scales suggest the teeth—four long rows of sharp pegs, fitted in sockets, a feature that does not occur in any other living creature outside the class of Mammals. If a tooth is broken there is another one almost ready beneath it, and beneath that another, and another, like thimble within thimble, an arrangement which mammals might envy! *Round about his teeth lieth terror,* and again, *At his teeth are the mighty dismayed.*

But besides the teeth there is a formidable equipment in the tail, one stroke of which may kill a man instantaneously. It makes a powerful swimming organ, flattened from side to side, and displacing a great mass of water to each side alternately. *In his wake is a shining path—one would think the deep to be hoary.* A curious feature is the scenting of the water with the musky secretion of two pairs of **odoriferous glands,** one pair under the throat and the other beside the end of the food-canal. In this way, perhaps, the leviathans are able to track one another in the river.

Crocodiles bask on the mud-banks during the day, apparently asleep, but quick to plunge into the water if they hear or see anything unusual. As Herodotus truly said, a kind of plover may often be seen in the company of the basking and gaping Nilotic crocodiles, and it is quite possible that it may enter the cavern of the mouth and pick parasites from the reptile's gums. It is often seen on the crocodile's back, and its alarm cry and fluttering wings may sometimes serve as a danger-signal to its drowsy friend.

It is at night that hunger sets the monster moving, and his mill has a heterogeneous grist. Mill is the proper word, for there is a strong muscular **gizzard** with grindstones in it—anticipating that of grain-eating birds. Sometimes it is a fish that is caught in the stream, sometimes a bird swimming on the surface, sometimes a young antelope that came to the margin to drink. Big booty has to be drowned, and in this process the crocodile not only closes his nostrils and ears, he shunts his windpipe forwards to meet the posterior opening of the nasal chamber (**posterior nares**). The position of this opening is unusual in being at the hindmost end of the bony palate. Thus no water can go down the wrong way, and the crocodile drowns the young antelope without drowning himself. In many cases a biggish animal is buried till it becomes high; so part of the night's proceedings is to unearth previous kills. In some cases there is a malodorous larder in a long burrow in the bank.

There are large **lachrymal glands** and, we suppose, big tears, *lachrymae crocodili*, which used to crystallize into gems. Of a truth the wateriness of the crocodile's eye is better known to the poets than to the zoologists. Spenser tells of the 'wearie traveller' who meets the 'craftie Crocodile,'

Which in false grefe hyding his harmefull guile,
Doth weepe full sore, and sheddeth tender tears;
The foolish man, that pities all this while
His mournful plight, is swallowed unawares,
Forgetful of his owne that mindes another's cares.

It is interesting to notice the rise of scepticism, for the author of the *Speculum Mundi* refers with dubiety to the story that when a crocodile has devoured a man all but the head, it will sit and weep over the remains of the grim meal. It is 'as if he expressed a great portion of sorrow for his cruel feast, but it is nothing so, for when he weeps it is because his hungrie paunch wants such another prey.'

The weak point of Leviathan is his brain. *Of his limbs I will not keep silence, of his strength and his mighty equipment* (Job xli 12), but his brain is beneath contempt. Within the huge skull, often over two feet long, there is a minute cranial cavity for a brain no longer than one's first finger, and not nearly so thick. A hen would be ashamed of the crocodile's brain. It indicates a rather frog-witted giant, who succeeds by bluffing with his sheer strength. Keeping to Professor M'Fadyen's translation:

No sword availeth against him,
Nor spear, nor dart, nor arrow.
He counteth iron as straw,
And brass as rotten wood;
Clubs are counted as reed,
And he laughs at the whirr of a javelin.

But he has not the brains of a domestic hen (q.v.).

The best of an animal is often seen in its maternity, and that is certainly true of the mother-crocodile. In the Nilotic species a hole is dug in white dry sand to a depth of a foot and a half or so, and there the numerous eggs are laid and covered up. Then there is another laying, and the hole is filled with sand. The mother often sleeps just above the nest, which is not a wise thing to do as far as man is concerned. The hard-shelled white eggs are like those of geese, and they take about three months to hatch out. The newly hatched crocodile is ever so much longer than the egg, within which it must therefore have been neatly coiled up. There is a boring egg-tooth on the tip of the snout, which is used in breaking out of the egg-shell, just like a

similar structure in many birds. It is a good example of an effective structure that is used only once in the lifetime. It disappears about a fortnight after hatching. To be born underground would be awkward



FIG. 205. YOUNG CROCODILES AND EGGS

for a creature of high degree like a crocodile, and so we find that the mother digs the eggs out just at the proper time. She seems to be instructed by a hiccupy piping sound that the young ones make from within the unchipped shell. When the young ones emerge the mother takes them to the water and continues her maternal care. But most of the large family fall victims to better brains before the apron-strings are cut. This must serve as our glimpse of the crocodile.



FIG. 206. HEAD OF GAVIAL (*Gavialis gangeticus*), A RELATIVE OF THE CROCODILE, COMMON IN THE GANGES

LIZARDS EVOLVING IN THE SUNSHINE.—Britain is not a friendly country for lizards, for they love to bask in the sun hour after hour, day after day, month after month. So there are only three different kinds in Britain, and none of them can be called abundant. But there

are well-sunned banks in the south of Europe where lizards may be seen in hundreds. They come out of holes in the walls that make the vineyard terraces, and on open paths they bask in crowds, shooting out their tongues on the still more abundant insects. Lizards are very attractive, graceful, alert, and beautifully coloured, and, except the Mexican *Heloderm* or ' Gila monster,' none is poisonous.

One of the great haunts of lizards is in the Dalmatian Islands, where they are not only very numerous, but very variable. Just as we have a St. Kilda wren and an Orkney vole, so there are many varieties of lizard or *Lacerta* in the sun-baked islands of the Adriatic. They mostly belong to two species, *Lacerta serpa* and *Lacerta fiumana*, which seem to be descendants of an old-fashioned kind that inhabited that corner of Europe long ago when Italy and Dalmatia were joined across the upper end of Adria. Some of the islands conserve this ancestral type. But the interesting point is that the two species just named, which include the majority of the lizards on the Dalmatian Islands, are nowadays splitting up into a large number of **varieties,** which breed true.

In short, **evolution is going on** apace in these sunny isles; and it is easy to understand that when a new departure or variation appears in an insulated species, especially when in several members at once, it is more likely to succeed than would be the case on the mainland. On an island the range of intercrossing is reduced in proportion to the size of the area. These island-lizards have been carefully studied by a distinguished zoologist, the late Dr. Paul Kammerer, of Vienna (well known as an experimental champion of the Lamarckian theory that new characters individually acquired by parents, as the direct result of peculiarities in environment or food, use or disuse, can be transmitted in a representative way to the offspring).

In what is going on among the island-lizards Kammerer found support for his Lamarckian conclusions, but without wading into these deep waters let us look at some of the pictures he has given of the life the lizards lead.

Some of the lizards are varying in the direction of darker colours and some are changing towards lightness. Warmth and drought make for blackness; cool and damp surroundings turn the tiller in the opposite direction, but whether directly or indirectly who shall say? Some varieties are becoming larger, others smaller; some are growing stouter, shorter tails, and others longer, thinner ones; some are developing smaller scales, others larger; some are becoming slower and tamer, others are increasing in agility and shyness. There is a very remarkable parting of the ways, a forking or dichotomy in the evolution that is going on; some are saying 'Shibboleth' and others 'Sibboleth'. This seems to be one of the common rules of evolution—often broken, no

doubt—that new departures are *plus* or *minus*, towards greater activity or towards less. This also applies to ourselves!

Although there are variations in both directions, the characteristic of the island-lizards is their tameness, as compared with those on the mainland. It seems to be a constitutional peculiarity, quite different from sluggishness; it has something to do with an intrinsic inquisitiveness, and something to do with a tendency to economize energy by suppressing useless movements. For the plain fact seems to be that these island-lizards have no enemies, except one another when overcrowding induces cannibalism. They are agile enough in catching insects, agile enough if there is any need, but in the absence of enemies it pays not to be shy.

'Anthropophily' (*anthropos*, man; *philia*, love) is the sort of word that the Germans like, and it ought to mean when applied to lizards that they are fond of man. But when we inquire further into the matter we find that the lizards do not get beyond a very cupboardish affection. They certainly abound in the vicinity of human dwellings; but this is because the creviced walls offer convenient homes, and because the dungheaps breed insects, slugs, and worms. That there is no personal affection for man is shown by the fact that deserted steadings are much frequented by the lizards. Thus the less said about 'anthropophily' the better!

Although the lizards of the Dalmatian Islands do not care for human beings in any direct way, their relations with gulls are different and somewhat surprising. There is the beginning of a **partnership** or **mutualism.** Several lizards may be found sheltering under the wings of a young gull before it has learned to fly, and this seems to be a habit on the Scoglio Islands, which are used by the gulls as breeding-places. The lizards are no doubt attracted in part by the insects that congregate on the droppings of the gulls and on the 'crumbs' from their table; but an examination of the food-canals shows that the lizards also eat mites and other body-parasites of the gulls. They show no anxiety in moving about among the gulls, and they have no need to be afraid; but the new point is that the lizards shelter under the wings of their friends!

Natural History pictures are always interesting, and we are indebted to Dr. Kammerer for his lively delineation of the crowds of lizards on these scores of sunny islands. But there is a deeper fascination in the biological picture of *individuality* and of *flux*. Just as no two human villages are alike, so it is said that no two islands have an identical lizard population. Basking in the sun, careless and free, the lizards have nothing to do but change. They are sending their evolutionary tendrils out into the future and making **new species** before our eyes. Evolution is going on.



FIG. 208. HORNED 'TOAD'
(*Phrynosoma cornutum*)

This animal is not a toad but a short, flat, spiny lizard with a very much reduced tail. It lives in the semi-arid regions of South-west Mexico.



FIG. 207. FRILLED LIZARD
(*Chlamydosaurus kingi*)

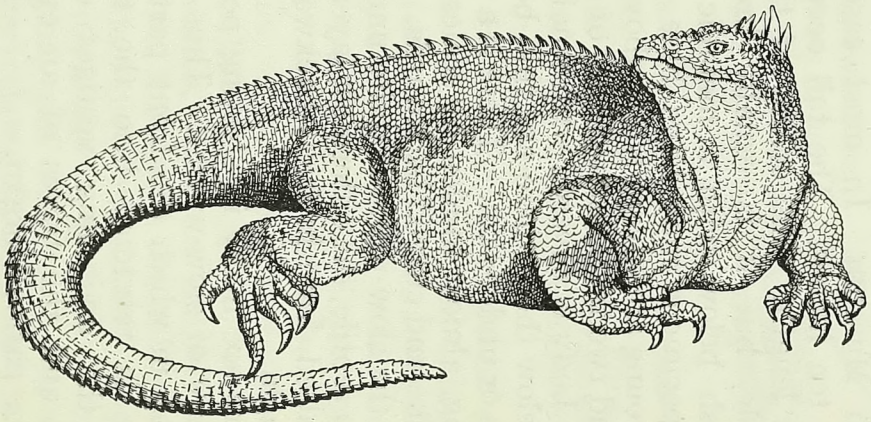


FIG. 209. AN IGUANA (*Iguana*), AN ARBOREAL LIZARD

THE SLOW-WORM (*Anguis fragilis*) is a limbless lizard with a snake-like body, not uncommon in some parts of Britain. It is sometimes miscalled blindworm (q.v.), but the eyes are well developed. Another popular impression, that it is poisonous, is quite false. It is harmless and feeds on earthworms and slugs, sometimes also on insects and spiders. It likes dry grassy places with shade and shelter in the herbage and heather.

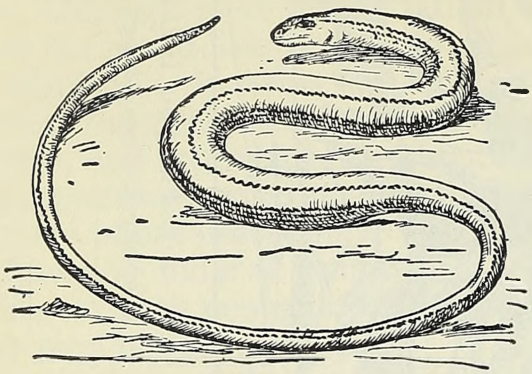


FIG. 210. THE SLOW-WORM (*Anguis fragilis*)

A large slow-worm may be a foot long, and there is a giant specimen of seventeen inches in the British Museum. In most cases the length is about ten inches. The tail occupies nearly half of the length. The colour of the body is very variable, but it is usually brown above and blackish below, with a metallic sheen all over. Old specimens may have blue specks, and the very young are silvery white above, with a median line and two more lateral lines of deep black.

The body is covered with small rounded scales, and below these there are thin bony plates in the dermis or under-skin. There is a very minute ear-opening, almost hidden by scales. The teeth are fang-like and curved backwards. As in snakes, to which the slow-worm is quite unrelated, except in being a reptile, the outermost layer of the epidermis is moulted, from in front backwards, in one piece or **slough.**

There are many interesting peculiarities in the structure of slow-worms. Thus we may refer to the way in which the front part of the notched tongue is retracted into the thicker posterior part, the dwindling vestiges of the pectoral girdle, and the traces of an eye in the pineal body or parietal organ.

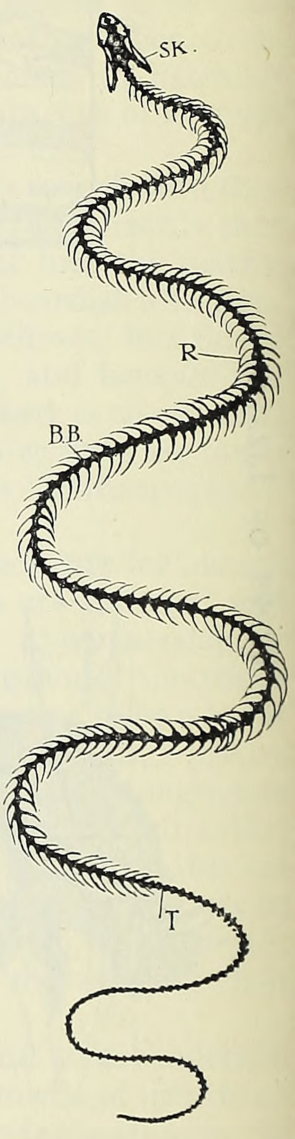


FIG. 211. SKELETON OF SLOW-WORM

SK, skull; R, rib; BB, backbone; T, tail.

As the specific name, *fragilis*, suggests, the slow-worm is liable to break in two. When captured it becomes rigid with strongly con-

tracted muscles, and a slight twist suffices to break off the tail. This surrender of the tail is common among lizards, and there can be little doubt that it often saves the animal's life. What is lost can be subsequently regrown if the mutilated creature escapes, but the part that replaces what has been lost is rather a makeshift. The self-mutilation or **autotomy** is a **reflex action,** not deliberate.

About a dozen silvery young ones are born at a time, in the month of August or September. They are fully developed when they are born, bursting out of the soft-shelled eggs as soon as these are laid. The newly hatched little creatures are about one and a half inches in length; they double this in about six weeks; but they take four or five years to become full-grown.

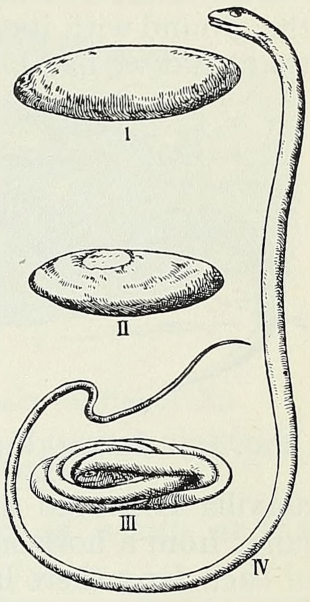


FIG. 212. FOUR STAGES IN DEVELOPMENT OF THE SLOW-WORM

The slow-worm is a shy, timid creature. It is active during the day, but prefers shady places, especially when young. At night it hides under moss or stones, or in the ground. When autumn comes a number—as many as two dozen—retreat together into a common burrow in some warm dry place, and pass into a semi-latent state. They emerge from their retreat in April or May.

It may be useful to reiterate that the slow-worm has, apart from its limblessness, no resemblance to snakes. Without going into details as to the entirely different skull, ribs, scale-arrangement, and soft parts, we may point out that the slow-worm has always vestiges of the pectoral and pelvic girdles, whereas snakes never show any trace of the former, and only in rare cases (e.g. *Boidae*) a hint of the latter; that it has a relatively long tail, whereas snakes have a relatively short tail; that it has movable eyelids, which are quite rudimentary in snakes. The slight superficial resemblance to snakes is technically called **convergence**—a similar adaptation to similar conditions of life. Apart from some other limbless lizards, a convergence to snake-like shape is also seen in the burrowing *Caecilians*, the true **blindworms,** which are Amphibia.

The slow-worm, which occurs all over Europe, is the only species of the genus *Anguis*; it belongs to the widely distributed family *Anguidae*, which includes the '**glass-snake**' (*Ophisaurus apus* or *Pseudopus pallasi*) of South Russia, Asia Minor, and Morocco—a snake-like lizard about a yard in length. Other related forms occur in North America and India.

VENOMOUS VIPERS.—Snake-bite does not count for much in

Britain, for there is only one poisonous snake, the adder or viper. We once watched a large specimen basking in the sun on the top of a boulder by the side of a narrow road in a Highland glen. The boulder was big enough to carry some heather, blaeberry bushes, and grass; and the adder was lying picturesquely on a shelf, evidently enjoying its sun-bath. It seemed to be nearly two feet long, but the biggest adders are those which are not caught. And why should one catch them? As the beautiful creature pulled itself together and slipped away, rowing on the ground with its ribs—a nullipede become a multipede—we realized that what we had been staring at, as unusual to our British experience, was one of the commonest sights in warm countries.

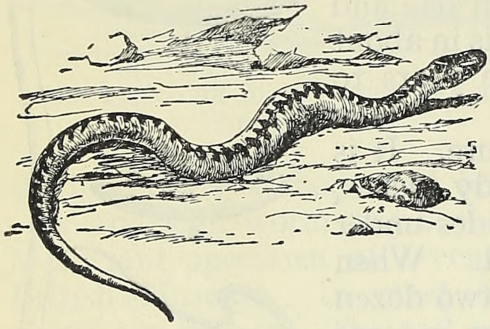


Fig. 213. Adder (*Viperus berus*)

The rare British casualty of an adder's bite is full of interest. The instruments are two sharp-pointed fangs or teeth, carried by the maxillary bones. Each has been folded on itself so that a canal is formed down the centre, and this opens by a minute pore near the tip. When the excited adder opens its mouth to strike, the maxilla is moved by an effective system of levers, and switches the fangs from a horizontal to a vertical position. In a sheath at the root of each fang there lie about ten reserve and developing fangs. If the functioning pair are injured there is another pair lying ready to take their place; and, as a matter of fact, the fangs periodically fall out, and are replaced after they have done duty for a considerable time.

Just as a fang is simply a highly specialized tooth, so the poison-making organ is derived from one of the salivary glands. When the adder's mouth is opened to strike, there is an automatic compression of the poison-gland on each side of the back of the mouth, and a minute quantity of the venomous secretion is squeezed forward to the root of the fang. It is then forced up the central canal and injected into the wound. As one of the greatest authorities on Reptiles well says: 'This is a perfectly devilish contrivance, ensuring the conveyance of the poison into the very deepest part of the wound.' The poison acts rapidly on some kinds of animals, such as mice; and it must be an advantage to the adder, which has a delicately built skull, to have this method of putting an end to the violent struggles of its booty. But Mr. Norman Morrison, of Campbeltown, who has had a long experience of adders, maintains that the frog, which is a common victim, is quite immune from the venom. Others hold that the frog's nervous system is poisoned, though the blood-cells are not dissolved as they are in the mouse. Mr. Morrison also points out that an adder can bite and

discharge poison six times in rapid succession, after which the supply is exhausted, till the gland has had time to make more.

The **poison** of the adder is of a protein nature, evidently very complex. It has a paralysing effect on the nervous system of the bitten animal; and that is naturally followed by a slowing or fatal stoppage of the breathing movements, and by a great diminution of the blood-pressure. In other words, in man's case, the breathing is heavy and the pulse is feeble. There is burning pain around the bitten part, and discoloured swelling sets in. The patient is depressed and sickish, with cold, clammy perspiration. But the severe symptoms usually pass off in twelve to twenty-four hours, and really serious cases are rare. Out of over two hundred bad cases in Germany in the course of ten years only fourteen ended fatally; and much depends on the patient's state of health at the time.

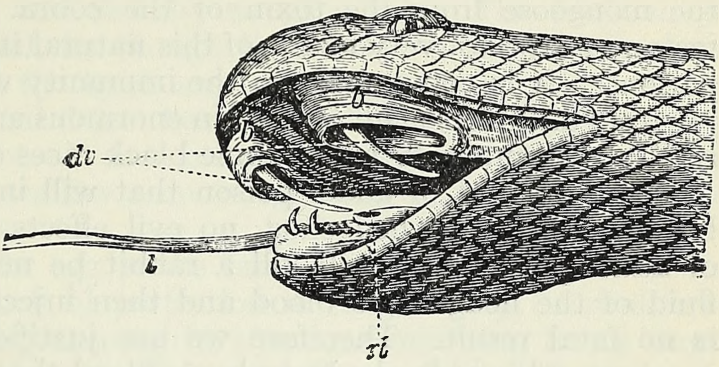


FIG. 214. A SNAKE'S HEAD.—After Nuhn

dv, poison-fangs; *b*, sheath of fang; *l*, tongue; *rl*, muscles of tongue.

The commonest place for an adder to strike a human being is above the ankle. A string should be tied tightly above the bite, to keep the poison from passing into the general circulation. The wound should be widened, bathed, and pressed, and bleaching powder or Condy's fluid should be applied. The ligature must not be kept tight for more than half an hour, but after the circulation has returned it may be applied again. The best internal stimulant is a little ammonia. The best antidote, apart from artificially produced serum, is the adder's own **bile.**

The hedgehog is an inveterate enemy of the adder, and it is not a very easy creature to bite. But even if the hedgehog were bitten, nothing would happen, for the hedgehog has somehow become **immune** from the adder's poison. This probably means that the blood of the hedgehog contains a counteractive or **anti-body** which neutralizes the poison. The pig is another creature that enjoys immunity, and the same seems to be true of the honey buzzard. If one adder bites another, nothing happens; in natural conditions it is immune to its own kind of poison. Yet a very heavy injection of adder-poison into an adder will kill it! This is a very intricate subject, requiring further study. Thus, although a cobra does not poison another

cobra, its bite may be fatal to another kind of snake. Here we get into the deep waters of bio-chemistry.

IMMUNITY.—But let us linger for a little over this question of venom and immunity. If a hedgehog is bitten by an adder, or a mongoose by a cobra, nothing happens. There is a something—called an **anti-toxin** or anti-body—in the blood of the hedgehog or the mongoose which neutralizes or counteracts the snake's venom. We say that the hedgehog is *immune* from the toxin of the adder, and the mongoose from the toxin of the cobra. There are some other instances, but not very many, of this natural immunity from particular poisons. It is comparable to the immunity which Algerian sheep enjoy from anthrax bacilli (except in enormous artificially injected doses), and to the immunity which some black races enjoy from yellow fever.

If the amount of adder-poison that will immediately kill a rabbit be injected into a hedgehog, no evil effects follow. If the amount of adder-poison that will kill a rabbit be mixed with the serum or fluid of the hedgehog's blood and then injected into a rabbit, there is no fatal result. Therefore we are justified in saying that there is a ' something ' in the hedgehog's blood that blunts the effect of the poison. What the 'something' is or how it works we do not clearly know. The ' something,' whether it is substance or quality, is real; but it has not been isolated.

When a pig is bitten by an adder nothing serious happens, and an injection of snake-poison under the pig's skin is not followed by evil effects. It might therefore be inferred that the pig is immune in the same way as the hedgehog or mongoose. Yet Calmette showed that if an amount of snake-poison, known to be a fatal dose for a rabbit, be mingled with the serum of pig's blood, and then injected into a rabbit, the result is fatal. Therefore it must be concluded that the pig's blood does *not* contain an anti-toxin like that which saves the life of the hedgehog or the mongoose. Why then does the pig remain insusceptible to the adder's bite or to the subcutaneous injection of venom? The answer seems to be that the familiar layer of fat below the pig's skin, a layer with very little in the way of blood-vessels, serves as a sort of sponge that absorbs the poison, and does not allow it to pass into the general circulation. One wishes that all the puzzles of immunity were as easily solved as this one! We have given no more than a glimpse of a deep problem.

THE EGG-EATING SNAKE.—Most animals, as we have often noticed in this book, are bundles of fitness, and there is no finer example than the egg-eating snake, *Dasypeltis scabra*. It is the only species of its genus, and it is at home in tropical and South Africa. It is related, not very distantly, to the British smooth snake, technically called *Coronella*.

Dasypeltis is of a light brown colour, spotted with black, but rather variable, as many snakes are. It is inconspicuous against dry ground. It might be called a rather 'drab' snake. A big specimen may attain a length of two and a half feet, but most that have been accurately measured are smaller.

We do not know that there is anything anatomically remarkable about Dasypeltis except its egg-breakers and its poor set of teeth. It has five teeth above and four below—a very small number; they are feeble as well as few; and thereby hangs a tale. The teeth might almost be called **vestigial,** for though the snake will snap viciously at an investigator's hand, the teeth are not strong enough to break the skin. This constitutional defect has led, we believe, to the specialization of the snake's diet—it has become a specialist in birds' eggs. A big Dasypeltis can swallow a hen's egg, and one only a foot long can swallow a pigeon's.

This is a feat, for the egg seems far too large for the size of the snake's head. The touch of perfection is that the egg is swallowed whole. There is nothing unusual in a snake swallowing booty larger than its head, for our grass-snake can swallow a frog, and the rattlesnake can swallow a young rat. The two halves of the snake's lower jaw are not fused together in front, as is usual in the higher backboned animals, but remain separate with only an elastic ligament connecting them. Moreover, it is characteristic of a snake's skull that most of the bones are movable except those that form the brain-box. Thus most snakes can swallow booty larger than the size of their head; and so it is with Dasypeltis, but there is more than that.

Having a poor set of teeth, Dasypeltis has become an egg-eater, and in the course of ages a remarkable adaptation has arisen. We take our facts from Mr. Fitzsimmons's valuable book, *The Snakes of South Africa,* which is full of first-hand observations. In the region of the neck of Dasypeltis the vertebrae have long inferior processes or hypophyses. These inferiorly exaggerated neck vertebrae extend over a length of about three inches, and they end in a few large ones whose tips project far into the gullet and are thickly covered with enamel. These are the **egg-breakers.** Behind these again there are seven more, projecting far into the gullet, but without enamel. These are said to keep the egg in place in the gullet, while it is being cut open. The presence of tips of enamel on the inferior processes is almost incredible.

The snake seizes the egg endwise, gripping it with its feeble teeth. After the usual fashion of snakes, it moves one side of the lower jaw forwards, while gripping with the other, and then does the same on the other side. There seems to be a succession of slow gulps and a forward movement of the body. The egg is then gripped by the

muscular pharynx, whence it slips into the gullet, which becomes extraordinarily distended. On the egg goes till it reaches the forward-directed enamelled projections of the vertebrae, where a neat operation is effected. The snake lifts its head an inch from the ground, and then, working its backbone backwards and forwards, cuts the egg-shell longitudinally as if with a fret-saw. It is a process of filing. Then the neck muscles are contracted from side to side, constricting the shell so that all the precious contents are squeezed out. If the egg-shell were broken in the mouth, much of the white of egg and yolk would overflow, but not a drop is lost by the neat arrangement of opening the egg when it is well down the gullet.

The conspicuous dilatation on the gullet suddenly disappears when the shell is cut and crushed inwards. Then the snake raises its head a little more and casts out the broken pieces. There is a touch of perfection in this 'returning the empties,' but it must be noted that they are returned in a very bad condition.

No one can deny the detailed fitness of this particular **adaptation.** In all probability, the constitutionally poor dentition led the animal to a very specialized diet, and the variation in the length and sharpness of the inferior processes of the vertebrae followed later. Out of a weakness Dasypeltis has made a new strength. The adaptation is one of the neatest ever described, but it should be noted, in illustration of Nature's evolutionary method, that nothing new is involved.

But even when we have pictured the variations and siftings of teeth and vertebrae for millennium after millennium, the animal doubtless playing its hereditary cards for all it was worth, the wonder remains that living creatures are able thus to change and change until the outcome is a perfect fit.

TWO-HEADED SNAKES.—Two-headed snakes, often referred to in legendary literature, are actual occurrences and many museums have specimens. Thirty-one cases of two-headed grass-snakes are known, and thirteen of adders. At least two dozen other cases are distributed among twelve genera, including the cobra and several sea-snakes. Three-headed snakes are not known, however, except by hearsay.

One of the earliest papers on two-headed snakes, by Mitchill in 1826, bears the title: *Facts and considerations showing that the two-headed snakes of North America and other parts of the world are not individuals of a distinct race, but universally monsters.* That is what they are—'monsters,' like two-headed calves and two-headed kittens and two-headed trout. In some cases there are two heads borne by a single body; in other cases the duplicity extends for a considerable distance backwards, so that the animal has an appearance somewhat like a letter Y.

Another quaint type consists of two heads closely united together, followed by two quite distinct bodies. In a variety of ways the embryonic foundations are duplicated. Thus it may be that an injury to the developing embryo is followed by a 'regenerative growth' which is unnecessarily vigorous. By experiments by no means violent it is easy to bring about dislocations of the embryonic building material, or to prevent the growing together of those parts that should normally unite; and analogous conditions may occasionally occur in Nature.

There is a long series between a duplication of a head end and a duplication of the whole body such as is illustrated in Siamese twins. In 1684 Francesco Redi, who was one of the first to bring evidence against the doctrine of spontaneous generation, studied a two-headed grass-snake, and was prompted, as he said, 'to give a glance, by way of pastime, at the internal structure.' He found that the doubling of the internal organs extended behind the region of the double backbone, for there were two hearts, two stomachs, and two livers. Monster snakes occur, as we have mentioned, with two united heads and two separate bodies; but snakes with two tails and an otherwise single body seem to be unknown. This may be because the anterior region of the embryonic body has a more intense vitality (or metabolism) than the tail region, and has therefore a greater susceptibility to disturbing influences.

It is not very unusual to find a lizard with two tails, but this is a phenomenon somewhat different from having two heads. The lizard's two tails arise when the original tail has been lost in the fully formed animal, and the subsequent regeneration has been over-exuberant.

The two heads of a two-headed snake are not always quite the same, for the eyes to the outside may be much better developed than those to the inside which look at one another. Indeed, if the two heads are very close together there may be a fusion of the two internal eyes.

A few observations have been made on living two-headed snakes. Thus there is a record of a bicephalous adder that persisted in going round in a circle or in a close spiral, and since the regulation of movements is largely effected through the ear, one can understand that there may be difficulties involved in having four ears. It must indeed be embarrassing to have two brains, and while some observers have recorded that the two heads lived happily together, others have reported a certain lack of unanimity in the behaviour.

Thus Vsevolojsky writes: 'General Gherard, with whom our little animal lived for more than a month, thought he observed that the two heads often had different wills, and that it was almost always the left head, apparently the more vivacious, that prevailed, which

sometimes seemed to annoy its neighbour. Such are the troubles of duplicity.'

The same author notes that the people of Astrakhan have a special name for a two-headed snake, and this seems to indicate a common occurrence. It is almost certain, however, that the reference in this case is to some limbless burrowing lizard, like *Amphisbaena*, where the tail end is so like the head end that one might be excused for calling the creature 'bicephalous.'

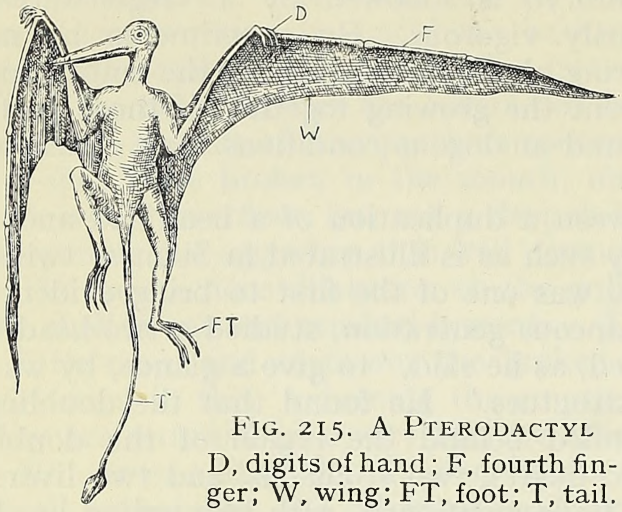


FIG. 215. A PTERODACTYL
D, digits of hand; F, fourth finger; W, wing; FT, foot; T, tail.

FLYING-DRAGONS. — The 'flying-dragons' or *Pterodactyls* were more or less aërial reptiles that flourished in Triassic, Jurassic, and Cretaceous times, and they illustrate one of the solutions of the problem of flight. A fold of skin beginning at the base of the neck was stretched on the outermost or fourth finger and extended to the five-toed hind-legs. In one section (the

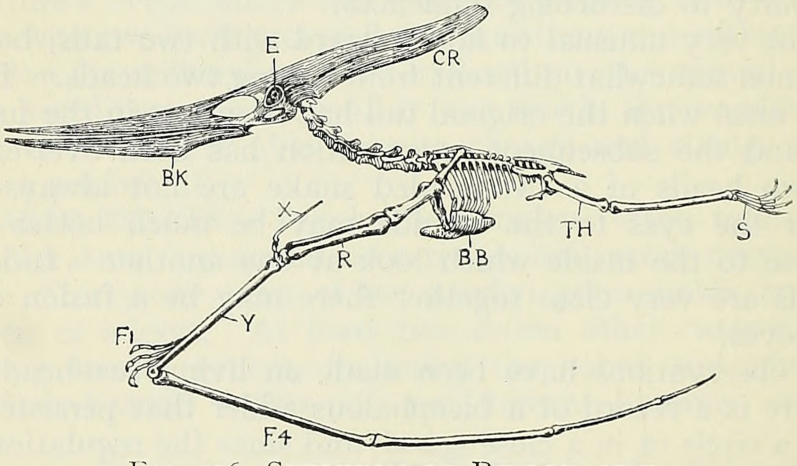


FIG. 216. SKELETON OF PTERODACTYL
E, eye-socket; CR, bony crest; BK, lower jaw; TH, thigh-bone; S, bones of foot; BB, breastbone; R, radius; X, extra bone arising from wrist; Y, carpal bone; F1, first finger; F4, fourth finger, much elongated and serving as support for the stretched skin forming the wing.

Rhamphorhynchus types) there was a long rudder-like tail; in the other section (the *Pterodactyl* types) the tail was very short,[1] and the posterior part of the skin-wing was spread out behind on the hind-legs. In all

[1] The short-tailed forms were able to 'take off' at a very steep angle, as in certain modern aeroplanes with reduced 'tails.'

cases the first three fingers were relatively small, and were probably used for gripping the surfaces of rocks and trees. In all cases the main support of the wing was the fourth finger, the little finger being always suppressed.

Some pterodactyls were no bigger than sparrows, but there were a few giants attaining to a wing-span of twenty-four feet. The modern albatross may have a span of nearly half that. From the detailed structure it is inferred that some types were no more than parachutists, holding their wings taut as they swooped from tree to tree. But others had true flight; that is to say, they were able to strike the air. Some of the pterodactyls probably flew over the sea, catching surface-swimming fishes. As knowledge of the fossilized remains increases, our knowledge of the flying-dragons becomes more intimate. Thus it has been suggested by Broili and by Wiman that they were covered, not with scales as reptiles should be, but with hair, and that they were warm-blooded. If this is substantiated, the pterodactyls would be the first animals with hair and with the power of sustaining a constant body-temperature. Another piece of news is that the web of the pterodactyl wing was sometimes stiffened by supporting threads of some sort. The bones of pterodactyls are pneumatic, as in birds, thus reducing the weight of the skeleton.



FIG. 217. A MODERN 'FLYING-DRAGON' (SO CALLED), A PARACHUTING ARBOREAL LIZARD (*Draco volans*) OF THE FAR EAST

The skin is extended on about half a dozen elongated and movable ribs. The illustration shows the parachute (i) extended as the animal leaps, and (ii) folded close to the side of the body when the animal is resting. There is no true 'flight,' and the parachuting mechanism in no way resembles the pterodactyl's wings.

DINOSAURS AND THEIR EGGS.—Numerous dinosaur eggs were found in 1922, by an American expedition, in the Desert of Gobi in

Mongolia. The American Museum of Natural History has the monopoly at present, and the price of an egg is two thousand dollars, which is about four times the price of the egg of the great auk, which was last seen alive about 1840. No doubt the dinosaur egg has this advantage over the great auk's, that there is no great risk of breakage. For these eggs are fossilized, practically turned into stone. They were probably laid many millions of years ago.

Why are these ancient eggs so interesting? First, because no one had previously seen a dinosaur's egg. Second, because one of them at least has inside it an embryo dinosaur, and with modern methods of seeing the invisible, it should be possible to do a little fossil embryology. What would be disadvantageous in a hen's egg purchased for breakfast would greatly enhance the value of a dinosaur's egg—we mean, having an embryo in its interior. Thirdly, the locality of the recent discovery of the dinosaurian treasures, which included skulls and skeletons as well as eggs, extends our knowledge of the geographical distribution of these extinct reptiles. Their remains have been discovered in Britain, Europe, Syria, India, South Africa, Madagascar, North Australia, South America, and North America. But now it is known that they lived and laid eggs in Mongolia. It may be that the American explorers discovered an ancient headquarters of dinosaurs, perhaps the headquarters from which migrants, crossing by the great Bering Strait land-bridge, colonized North America long, long ago.

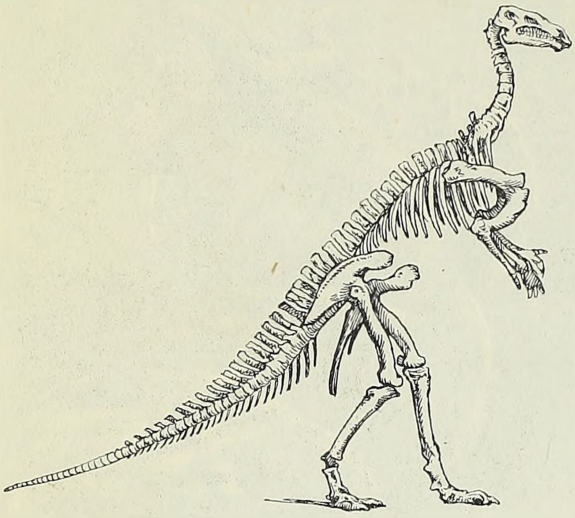
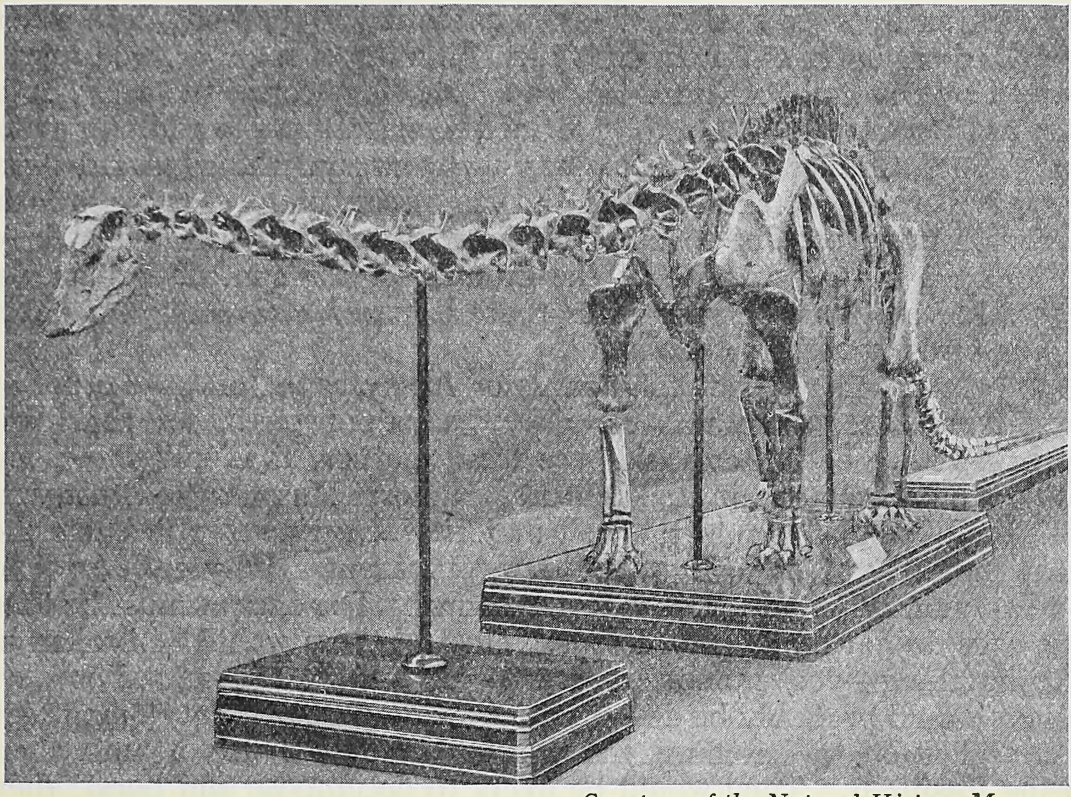


FIG. 218. SKELETON OF *Iguanodon mantelli*, AN EXTINCT BIPEDAL REPTILE ABOUT TWELVE TO FOURTEEN FEET IN HEIGHT

One of the sights of the world is the herd of *Iguanodons* in the Brussels Museum. Fossil dinosaurs, they are extraordinarily impressive, raising their massive bodies in kangaroo-like fashion, with their heads about fourteen feet off the ground. There are at least seven of them, dug out of a Belgian coal-mine. They give the visitor some idea of the extinct reptiles from whose fertile stock many long-lasting descendants sprang. The first iguanodons were found by Dr. Mantell over a hundred years ago in the strata known as the Sussex Wealden, but their impressiveness was hardly realized before the Belgian discovery of about half a century ago. They were bipedal vegetarian giants, perhaps living on the foliage of trees whose lower branches they

pulled down within reach of their mouth. The thigh-bone is about a yard long, and the claw on the thumb was over a foot.

Yet the proportions of the iguanodon were moderate compared with those of some other dinosaurs, for the thigh-bone of *Atlantosaurus* was six feet long, the hind-leg of *Stegosaurus* was twice the height of an average man, and the restoration of the great *Diplodocus* in the British



Courtesy of the Natural History Museum

FIG. 219. *Diplodocus*

Museum of Natural History shows an animal about eighty feet in length. They were not all giants, however, and some had delicate hollow bones like those of birds. They were terrestrial creatures for the most part, but some may have waded deep in river or sea. Some were vegetarian and others carnivorous. From the small size of their brain-case one is driven to think that most of them were rather stupid. They began in the middle geological ages called Triassic; they became dominant in Jurassic and Cretaceous periods; and then they disappeared, at a time when mammals began to fill the stage.

It is probable that birds evolved from bipedal extinct reptiles called *Pseudosuchians*, that took running leaps along the ground; and that mammals had their ancestors in another order of extinct reptiles—the *Therapsids*. But there is still some uncertainty, and the most

important fact to be quite clear about is that there was a time when the highest living animals were creatures like those dinosaurs which laid their eggs in the region now known as the Gobi Desert. Before there was any hint of bird or mammal the dinosaurs and their reptilian relatives were at the top of the genealogical tree.

There is nothing surprising in dinosaurs laying eggs, for they were reptiles, and most living reptiles are oviparous. In a few living reptiles, such as sea-snakes, the eggs hatch inside the body. In other words, there is true viviparous birth. In a larger number, well represented by the limbless lizard known as the slow-worm, the eggs hatch just as they are laid, and a fully formed miniature of the adult wriggles out. Such reptiles are practically viviparous, but the awkward term ovo-viviparous is often used. In the vast majority the eggs go through a considerable part of their development after they are laid. They are helped by the warmth of the ground, or the sun, or fermenting vegetable matter. In rare cases there is parental brooding, a habit which birds brought to perfection.

In some of the extinct fish-lizards or *Ichthyosaurs*, another order of extinct reptiles, there was certainly viviparous birth, for the fossil embryos have been seen inside the fossil mother, as is well shown by some fine specimens in the Natural History Museum in Stuttgart. But the likelihood is that the vast majority of extinct reptiles, like the vast majority of living reptiles, were oviparous. Why then had no one previously found the eggs of dinosaurs? The answer must be that the eggs do not make good fossils. Most of them would be broken in the hatching—you cannot expect to have both egg and dinosaur; others would probably be devoured; and in any case, if developing eggs were killed before hatching, the chances are enormously against their being fossilized. They would be likely to decompose and burst; they would not be able to withstand the fossilizing pressure. So the American explorers were extraordinarily lucky in finding numerous dinosaur eggs.

THE REPTILIAN RETURN TO THE WATER.—A common sight on tropical shores is the ' mud-skipper ' (*Periophthalmus*), a fish out of water (see Fig. 439). It jumps about among the rocks, hunting small animals, or it climbs on the aërial roots of the mangrove trees and looks round with its strangely protruding eyes. Now this fish, which does not stand alone, is a hint of the transition **from water to dry land** which was one of the greatest events in history. In the mud-fishes, again, we have to deal with pioneer types in which the swim-bladder has been transformed into a lung, able to breathe dry air. From fishes distantly related to these double-breathers (with lungs as well as gills) there arose the amphibians, which made, as far as backboned animals are concerned, the epoch-making transition on to terra firma. Every one knows how

terrestrial a toad has become, but in almost all cases the amphibian must return in its youth to the cradle of its race and pass through a juvenile or tadpole period in the fresh water. From amphibians sprang reptiles, thoroughly terrestrial at last, and from reptiles there evolved both birds and mammals.

The possession of the dry land was a great step, but there was a tax to pay. It implied a loss of the aquatic freedom of movement, an increased risk in the disposal of the eggs and the young, a need for having a thicker skin. This thickening put an end to all possibility of skin-breathing and made the capture of oxygen more difficult, though the available supply is much greater on land than in water. How these difficulties were met in various ways—by making hidden nests, for instance, and by gaining the *internal surface* of the lungs for capturing oxygen—is an interesting inquiry; but we are concerned at present with the fact that many terrestrial animals have gone back to the water. No animal is more terrestrial than a snake, yet there are sea-snakes. Mammals certainly evolved on dry land, yet the whole order of whales consists of aquatic mammals.

Four or five times in the history of animal life there has been a colonization of the dry land—by worm-like creatures, by air-breathing, jointed-footed (*Arthropod*) types, by lung-possessing molluscs, and by the ancient amphibians. Each conquest must have taken a long time, and must have involved severe sifting. Why, then, should some of the conquerors go back on their own tracks and return to the water? The answer is probably stress of circumstances. Over and over again there have been periods of aridity, making the dry land a difficult home and prompting a change. The same would be true of local drought, of volcanic eruptions, of fires, and of overcrowding on a small area.

Many of the extinct reptiles were aquatic, but there is strong probability in favour of the view that these represent secondary returns to the water, not primarily aquatic types. The great evolution of reptiles in the Permian was on dry land in somewhat warm and arid conditions; but in no less than eleven out of the eighteen orders there was some recolonizing of the water and a readaptation to aquatic life. As Professor H. F. Osborn indicates, the return was probably gradual, through marsh and swamp, to river and sea. The place now occupied by the mammalian whales and dolphins was previously held by the reptilian *Ichthyosaurs*, *Plesiosaurs*, sea-lizards, and great sea-serpents —all of them lost races—and also by crocodilians and turtles, which have aquatic representatives to-day.

The modern palaeontologists have made the very dry bones of fossils live in an extraordinary way. They tell us how some of the swimmers moved by paddles, as in the case of *Plesiosaurs*; and others by the

sinuous movements of the posterior body, as in the case of the fish-lizards; or how the *Ichthyosaurs* became viviparous, and were thus relieved from the need of coming to the land to deposit their eggs; or how the *Mosasaurs* (swimming reptiles) hunted active fishes which they made sure of with their recurved teeth. Very striking is the repeated appearance of similar adaptations, such as paddles, on lines of evolution which are quite distinct from one another. It is said that a race never regains characters which have been lost in the course of evolution; but, whether irreversibility in this sense is a Law of Nature or not, there is no doubt that Nature often repeats itself by evolving a similar structure, like a paddle, several times over, on different lineages.

The largest living turtle is the leatherback, which may be six feet long and weigh half a ton. It ranges over all the warm seas, but is nowhere common. It feeds on fishes, molluscs, and crustaceans, and does not come to land except to lay eggs. The carapace or external armour is quite unique, for it consists of small polygonal *bony plates*, embedded in a dense leathery skin which is without the usual horny scales. Thereby hangs a tale. For according to Dollo, the early ancestors of the leatherbacks were terrestrial creatures with a firm bony carapace, which was lost after they took to the sea. But after an age had passed, the softened leatherbacks returned to the shore and entered upon a secondary littoral life, during which they acquired a second bony armature on a different plan and pattern from the first. Finally, to quote from Professor H. F. Osborn's vivid *Origin and Evolution of Life*, ' descendants of these secondarily armoured, shore-living types again sought the sea and entered upon a secondary marine pelagic phase, in the course of which they lost the greater part of their second armature and acquired their present leathery covering, to which the popular name " leatherback " refers.' Of course, this is an *interpretation* of the distant past, and must not be accepted as more than hypothetical. What is certain is that the leatherback's carapace is like a palimpsest, as if an older writing had been partially erased and then covered over with another of more recent date. The leatherback has its limbs turned into paddles, as in the edible turtle and other marine turtles, and it is instructive to compare this thorough-going adaptation with the old-fashioned limbs of the aggressive snapping-turtle of the American lakes or with those of the European pond-tortoises. Where the life is less thoroughly aquatic, the adaptation of the limbs does not go so far in the direction of paddles.

The idea we are illustrating is the secondary return of terrestrial types to an aquatic haunt, and no better instance could be found than that of the sea-snakes. For the peculiarities of the limbless body of snakes are obviously in the main adaptations to progression on dry land, and taking to the water is a second thought. The true sea-

snakes are not related to the extinct sea-serpents or *Pythonomorphs*; they are derivatives of terrestrial types. They are fish-eaters, and very poisonous; their range is from the Persian Gulf to Central America. In adaptation to their aquatic life they show a compression of the tail from side to side, so that a sort of paddle results; and the flattening may involve part of the posterior body as well as the tail in the strict sense. The scales are small, and an interesting feature is the frequent suppression of the large ventral scales with which an ordinary snake grips the ground. Another adaptation may be found in the fact that they are all **viviparous**; but this mode of birth occurs also in many terrestrial forms, such as the vipers. A straw which shows how the evolutionary wind has blown is the habit that some of the mother sea-snakes have of coming to the sea-shore rocks when about to bring forth their young.

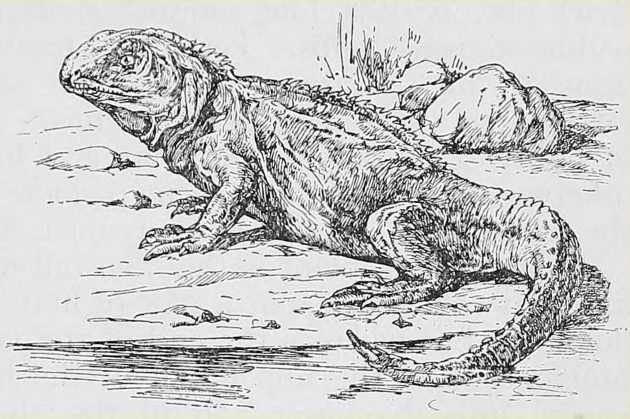


FIG. 220. THE TUATARA (*Sphenodon*)

From leatherbacks and sea-snakes our particular point is sufficiently illustrated; but there are, of course, other aquatic reptiles, such as the crocodiles, alligators, and gavials. That strange 'living fossil,' the 'tuatara' or *Sphenodon* of New Zealand, is fond of lying in the water, and can remain submerged for hours without taking a breath! The famous *Amblyrhynchus* lizard of the Galapagos Islands scrambles on the shore rocks for seaweed.

FISH-LIZARDS OR ICHTHYOSAURS.—The extinct reptiles called *Ichthyosaurs* were once common in the ancient seas; they ranged from the Triassic, through the Jurassic, to the Cretaceous, when they disappeared. We do not know from what simpler stock they may have been evolved, and we do not know that they had any descendants. Appearing in large numbers from an unknown ancestry, they had their Golden Age for millions of years. For some unknown reasons they then began to decline, and there is no trace of any after the Chalk period. Their remains show no particular resemblance to those of any other order of reptiles, extinct or extant; they form a somewhat homogeneous order, quite by themselves and in many ways unique.

We know that ichthyosaurs were marine and that they were carnivorous; that they varied in size from a yard in length to thirty or forty feet; and that, apart from the somewhat primitive *Mixosaurus* and the somewhat decadent *Ophthalmosaurus*, they were all very like one another, being similarly adapted to swift swimming in the sea

and to catching cuttlefishes and true fishes. This meant some expertness in swimming, and for this the shark-shaped or dolphin-like body was well suited. It says something for palaeontology that a diet of cuttlefishes can be safely inferred from the fossils, for the parrot-beak-like jaws, characteristic of cephalopods, are easily recognizable inside the petrified body of many an ichthyosaur. It may be that the huge appetite of the ichthyosaurs brought about the disappearance of some of the ancient types of cuttlefishes long since extinct.

Picture a lithe body, almost neckless, more porpoise-like than shark-like, with a long-snouted skull and two pairs of somewhat paddle-shaped limbs. Perhaps 'trowel-shaped' would be more accurate, for they taper to a point. On the back there is a jagged, fatty fin, or a succession of several fins. There may be some indication of horny scales about the front and base of the fore-paddles, but otherwise the fish-lizards seem to have been *smooth-skinned*, just as the mammalian cetaceans at a much later date became.

An interesting point is that the tail had a large bilobed *vertical* fin like that of a shark, not a pair of horizontal flukes as in whales and dolphins; but whereas the end of the vertebral column of a shark is prolonged into the upper half of the unsymmetrical tail, it is prolonged into the lower half of the also unsymmetrical tail of the ichthyosaur. When a shark strikes with its tail—upper half the larger—the movement tends to depress the head, unless, of course, the shark has turned upside down, as it often does, at the surface. But as the stronger half of the fish-lizard's tail is the lower one, into which the end of the vertebral column is abruptly bent, the stroke must have tended to bring the head up—and this would tend to lift the head and its nostrils upwards at the surface, an obvious **adaptation** for a lung-breathing reptile.

The skull is drawn out into a long snout, which is chiefly made up of the bones that are exaggerated to form the beak of a bird, namely, the premaxillae. As in all birds, except the kiwi, this reptile's nostrils are far back. The orbits for the eyes are remarkably large, and we know that the front of the eyeball was protected by a ring of bone —the **sclerotic ring.** But this occurred in many of the extinct reptiles and formed part of the legacy that was handed on (probably by the *Pseudosuchia*) to birds, the surprising scions of an adventurous, though somewhat markedly pedestrian stock.

On the top of the ichthyosaur's skull there is a well-marked hole —the parietal foramen—which lodged the **pineal body,** that strange, upward-looking median eye, represented in some degree in all Vertebrates from lamprey to man, but showing only in a few animals to-day, such as the New Zealand 'lizard' or *Sphenodon*, distinct traces of optic structure. It is the organ about which we are always told that

Descartes regarded it as the seat of the soul. If he did, it was very generous of him, for it means including as besouled the lamprey and the tadpole, the slow-worm and the ichthyosaur, and thousands of more ordinary Vertebrates, which have a pineal body as part of their make-up.

In most ichthyosaurs the conical teeth, suggesting those of some



FIG. 221. CHAMAELEONS (*Chamaeleo*)

These are strange lizards, mostly inhabitants of Africa. They have a remarkable power of changing their colour.

of the toothed whales, are placed in a continuous groove. They were evidently suited for seizing and gripping slippery prey, rather than for chewing. From the shape of the fossilized alimentary débris or dung (**coprolites**) it seems fair to conclude that the ichthyosaurs had a **spiral valve** like that of sharks, an ingenious spiral staircase inside the intestine which serves to increase the surface for absorbing the digested food. Thus of a type of animal that left the stage millions of years ago we can say that it was marine and carnivorous, that it bolted its food, that it depended chiefly on fishes and cuttlefishes, and found the chitinous beaks of the latter more difficult to digest than the bones of the former. Not less remarkable is the ocular demonstration of the fact that ichthyosaurs were **viviparous,** bringing forth their young ones as miniatures of themselves. In some specimens the

unborn fossil offspring are conspicuous inside the fossil mother. Thus the dead bones live!

The York Museum has among others a fine specimen of *Ichthyosaurus crassimanus*, which must have been about thirty feet long. It shows very clearly that the ordinary long bones of the limbs are in fish-lizards very short, the main part of the paddle being the hand or the foot. We counted the finger-joints beyond the wrist, and one had nine, instead of the usual three; in some cases the number rises to twenty. In all probability the chief swimming organ was the posterior body, including the tail, the paddles being used chiefly for steering and balancing. It was not advantageous that the paddles should be long, but they retained great developmental vigour, which found staccato expression in a multiplication of finger-joints. Sometimes, moreover, the third digit has been split longitudinally in the course of development, so that the number rises to six.

Lung-breathing animals could not have arisen in the sea, so we must look for the ancestors of fish-lizards among extinct terrestrial reptiles. In the yard-long *Mixosaurus* the limb is not so paddle-like as in typical forms; the teeth are not in a continuous groove; and the vertebral column is not bent down into the tail as much as usual. Thus even in regard to the peculiarly isolated ichthyosaurs there is evidence of evolution.

CHAPTER XX

BIRDS

General characters of Birds—Survey of structure and activities: Posture—Bills—Feathers—Colours of feathers—Skeletal adaptations—Flight of Birds—Brain, senses, and behaviour—Food—The alimentary system—Respiration—Vascular system—Excretion—Reproductive system—Birds' nests—The Brooding Bird—Migration—Carrier pigeons—Birds in their haunts—Interrelations—Achievements of Birds—Pedigree of Birds—Classification of Birds—Illustrations of Bird-life.

General Characters

Birds may be tersely defined as feathered bipeds, for these two words, taken together, exclude all other creatures. If we say *warm-blooded, egg-laying, feathered bipeds,* the definition would be still better. But it is too short and cold to suggest what birds really are, and there is need for some exposition of their general characters.

Birds live at a high pitch; their body-temperature is from 2° to 14° F. higher than that of mammals, and this gives some hint of the intensity of the chemical processes that are going on. The muscles are very highly developed; the heart beats quickly; the breathing movements are rapid; the blood is very rich in red blood corpuscles; the digestion is very perfect; the bird lives nearly up to its income.

There are a few **flightless birds** like the ostriches, but they are off the main track, and we must always think of birds as animals that have turned their fore-limbs into wings. Given fine muscles, rich blood, a strong heart, good breathing, we naturally expect rapidity of movements, and there is reason to believe that the ancestors of flying birds were rapid sprinters, able to take running jumps, and to parachute a little with their fore-limbs when they got up speed. There is no doubt that birds arose from some extinct stock of reptiles, probably from a stock known to experts as the *Pseudosuchia.* After a dangerous period of terrestrial life the ancestral birds probably became arboreal; and it was perhaps among the branches that parachuting changed into **true flying.** Necessarily the word ' perhaps ' must come in often when we are thinking of what happened several million years ago.

In reptiles and amphibians there is a marked imperfection in the arrangements for the circulation of the blood, for the blood that is driven from the heart to the greater part of the body is mixed blood, not pure blood. Except in crocodiles and their near relatives there is

in the heart an incomplete separation of the pure and impure blood, and even in crocodilians it is mixed blood that is driven to the bulk of the body. By ' mixed ' blood is meant that it is not so well oxygenated as pure blood, for it is a mixture of the blood that has been round the body with the blood that has returned purified from the lungs. But if the bulk of the body is supplied only with mixed blood (even fishes manage better than that !), it means a serious handicapping of activity. Thus we see the importance of the fact that in birds the body is supplied with pure blood exclusively. When this arrangement was perfected it must have meant a marked increase in bodily vigour.

Another great improvement that is seen only in birds and mammals is **warm-bloodedness.** This means the power of keeping the temperature of the blood constant, day and night, summer and winter. When the warm-blooded animal is losing too much heat on a cold day, nervous orders pass to the muscles from a **heat-regulating centre** in the brain, and more heat is produced. If the animal is becoming too hot on a warm day there may be an internal reduction of the amount of heat produced, or the creature may keep very quiet, or it may increase the evaporation of water from some surface. Birds have none of the sweat-glands that mammals have, but there may be evaporation of water-vapour from the internal surface of the lungs, as well as from the air-sacs into which these organs are prolonged. Birds often suffer considerably from the heat, and it is plain that their non-conducting coat of feathers will not help in the heat as it does in the cold. It may be noted that nestlings are apt to die quickly if the mother leaves them exposed, for the heat-regulating arrangements have not yet been established in the body, which is still continuing to develop.

Given intensity of vital processes (**metabolism**), active habits, rich blood, and a good circulation, it is not unnatural that there should be a high development of skin-structures, namely, **feathers.** There is also an abundance of blood-vessels in the bird's under-skin or dermis, from which the growing feathers are nourished. In a general way the feathers of birds may be compared with the scales of reptiles: both are made by the outer skin or **epidermis,** and nourished by the under-skin or **dermis.** But it must be kept in mind that birds have **scales** on their feet and bills, and that there is no intermediate stage between scales and feathers. In short, the origin of feathers remains obscure. That they must have been indispensable auxiliaries in the progress of the race of birds is certain, for the bird-wing is a *feather*-wing, not a *skin*-wing, as in bats. Feathers save the body from getting cooled down, like the rug thrown over the engine of a stationary motor car; and every one knows that they often form a life-saving quilt in the nest.

If we think again of a very active creature, richly endowed as regards muscles and skin, heart and blood, that had begun the habit of flapping

with its fore-limbs in its vol-planing from tree to tree, we can picture the beginning of the solution of the problem of **flight.** But let us notice some additional **fitnesses** that made the flight of birds almost perfect. The skeleton became more lightly built, with a large surface for the insertion of muscles, without a corresponding increase of weight. The breastbone acquired its keel, for the better fixing on (or *insertion*) of the wing-muscles. The lungs became fixed to the basket-work of the ribs in such a way that the actual flying helped the breathing by compressing the lungs. Moreover, the lungs, while remaining small in size, gained a very large internal surface on which the blood is spread out, and they were also continued into soap-bubble-like **air-sacs** that made the breathing more effective. It is noteworthy that in birds, as for the most part in insects, the breathing-out (*expiration*) is the active part of respiration, and that the flying helps in this. In mammals, like ourselves, the breathing-in (*inspiration*) is the active part of respiration; and a quickly running mammal is apt ' to get out of breath ' in a way that is very rarely seen in birds.

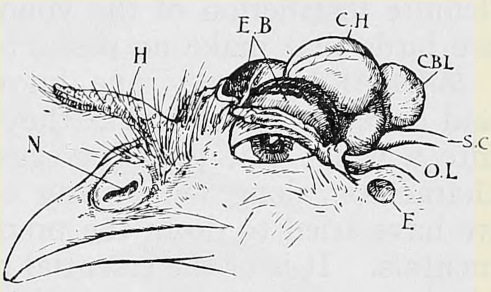


FIG. 222. HEAD OF TURKEY, PARTLY DISSECTED

N, nostril; H, horn; EB, eye-balls; CH, cerebral hemisphere; CBL, cerebellum; SC, spinal cord; OL, olfactory lobe; E, ear.

When we compare the skull of a bird with that of any reptile, the most striking of the many differences is that the brain-case has increased greatly in relative size. In birds the brain has somewhat abruptly come into its own, especially as regards the two very important parts called the **cerebrum** and the **cerebellum** (see BRAIN). Most birds are small creatures, high-strung and of delicate build, without much in the way of armour and weapons, and therefore much more dependent than reptiles on the possession of alert brains. The transition from terrestrial to aërial habits requires improved brains, for the brain was an organ for controlling movements long before it could do much in the way of thinking. The senses of sight and hearing mean more to birds than to reptiles, and this also involves the improvement of the brain. When we think of the strong current of feeling in birds, especially at the courting time and when the brood has to be cared for, we see another reason for better brains. In short, variations in the direction of better brains would be advantageous for many reasons, and would tend to secure survival for those birds that showed them (see EVOLUTION).

Terrestrial habits, as we have already noted, make it necessary to have some special provision to secure the safety of the eggs and

young. The circumstances are much more difficult than those of aquatic life. Thus some reptiles bury their eggs, as crocodiles do; some brood over them, as we see in pythons; and some hatch the eggs within the body, as in vipers and some lizards. But in birds the solution is neater, since the majority build nests off the ground. This nest-building was a very important step, for it made the safety of eggs and nestlings much more secure; it admitted of a prolonged development and infancy, so that the young creatures got a better start in life; it strengthened the emotional links between the two parents, and between them and the offspring; and it allowed of some definite instruction of the young in the art of life. No doubt there are birds that make no nests, but they are in a small minority.

SUMMARY.—Every one knows that modern birds are toothless and have horny bills, that they have had their arm and hand turned into a wing, that they lay eggs with hard shells, and so on. These characters, along with many others, are very important, but what we have tried to do in the preceding sketch is to get down to fundamentals. It is of the essential nature of the bird to have: (1) intensity of vital processes or metabolism; (2) a spare, very muscular habit of body; (3) rapid bipedal progression; (4) very rich blood and the body supplied with arterial or pure blood exclusively; (5) warm-bloodedness; (6) the respirations assisted by locomotion; and (7) a well-developed brain with big eyes. From these fundamental characteristics many others follow.

Survey of Structure and Activities

POSTURE.—There are several different poses of body among birds. In a bird like a duck, for instance, a considerable part of the backbone is in the main horizontal, and our general impression is that the creature is like a boat. Similarly in an ostrich the long mobile neck rises almost at right angles to the horizontal stretch of dorsal vertebrae. But in a bird like an eagle, for instance, the whole attitude is more erect; the back is nearer the perpendicular than the horizontal, and the neck is much more in line with the back. Many swimming birds show the boat-like build, but the members of the auk family, such as guillemots and razorbills and puffins, hold themselves very erect when they are out of the water and either resting or walking. A bittern is another bird that holds itself very upright; a solan goose or a gull may illustrate the more boat-like type.

BILLS.—Bills are very diverse and their shapes are usually suited for particular kinds of diet. We may contrast the delicate elongated bill of humming-birds, suited for getting nectar from tubular flowers,

with the short, strong, hooked bill of an eagle, suited for tearing the prey to pieces. Or the broad flat bill of a duck, suited for sifting the mud, may be contrasted with the long narrow bill of the woodcock, suited for probing for earthworms in the soft soil. The short, conical, strong bill of a bullfinch, suited for breaking into fruits and cracking seeds, is very different from the enormous bill of a pelican, suited for fish-catching.

A bill is the horny epidermic covering of the bony **beak**, and it is equivalent to the similar structure of the likewise toothless turtles. In some birds, such as the albatross, the bill is 'compound,' that is to say, it is made up of many parts, corresponding, no doubt, to separate scales in reptiles; while in the puffin there is an annual moulting of a considerable part of the laterally compressed bill.

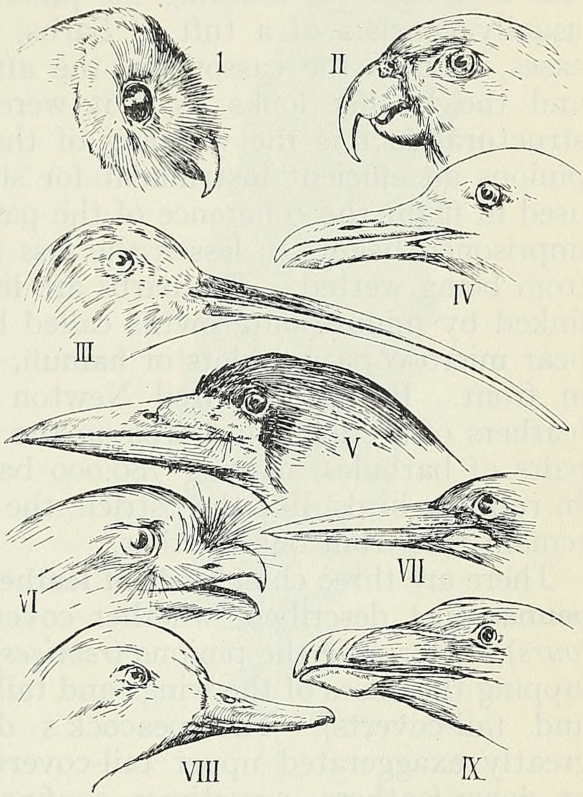


Fig. 223. Various Types of Bills in Birds

I, owl; II, parrot; III, curlew; IV, gull; V, rook; VI, goatsucker; VII, kingfisher; VIII, duck; IX, razorbill.

FEATHERS.—There is no connecting-link between a feather and an epidermic scale, but the development of the two structures is not very different. Both arise from expanded papillae of the epidermis, consisting of cells which become horny; and both are fed, as long as they grow, by pulp-like upgrowths of the under-skin or dermis, containing minute blood-vessels. Perhaps a feather may be thought of as the frayed-out base of a scale, and there can be no hesitation in comparing the scales on a bird's toes and instep region, as also on the bill, with the typical scales of reptiles. It should be noted, however, that what is moulted in reptiles is the outermost dead layer of the epidermis covering the scales, whereas in birds the whole feather is thrown off. There is an autumnal moulting of the scales of the bill in puffins and a moulting of claws in the grouse. We must admit that feathers are unique structures, whose evolution remains obscure.

An ordinary feather shows the following parts: (1) the cylindrical hollow barrel, quill, or **calamus**, with its base embedded in a moat or

follicle of the skin; (2) the main shaft or **rhachis,**[1] filled with white pith, and somewhat quadrangular in cross section, but convex externally and concave internally; (3) the **vane,** consisting of a bilateral web, which in the case of the pinions serves to strike the air, and is built up of biserial barbs united by barbules and microscopic barbicels; and (4) it may be, an aftershaft or **hyporhachis,** which arises to the inner side at a little pit marking the junction of calamus and rhachis, and usually consists of a tuft of barbs, often with barbules. In a few cases, such as the cassowary, the aftershaft is as long as the shaft, and the feather looks as if it were double. The most important structural fact is the webbing of the vane, so that it forms in the pinions an efficient instrument for striking the air. In feathers not used in flight the coherence of the parts of the vane helps to keep air imprisoned below, to lessen the loss of heat, and to protect the skin from being wetted. The barbs are linked by barbules, and these are linked by minute outgrowths called barbicels or **cilia,** some of which bear microscopic hooklets or **hamuli,** catching on to the barbule next in front. Professor Alfred Newton found on one of the primary feathers of a crane 650 barbs on the inner web, each with about 600 pairs of barbules, making 780,000 barbules for the inner web alone. In running birds, like the ostrich, the barbs, though bearing barbules, remain free from one another.

There are three chief **kinds of feathers.** First there are the ordinary **pennae** just described, whether covering the body as a whole (*contours*), or forming the pinions (*remiges*) and the tail (*rectrices*), or overlapping the bases of the wings and tail, above and below (wing-coverts and tail-coverts). The peacock's decorative tail consists of the greatly exaggerated upper tail-coverts. Second, there are **plumules** or down-feathers, sometimes confined to nestlings, sometimes persisting throughout life. They show a short calamus, no rhachis, and no union of barbs. Ducks have a strong development of down-feathers throughout life, whereas adult pigeons have none. Third, there are the delicate hair-like **filoplumes,** which have no more than a few barbs at the tip of the filamentous rhachis. The eyelashes, the bristles of the gape, and the hair-like filaments of some decorative tufts, are probably contour feathers reduced to the base and shaft. Apparently derivable from the plumule type are the curious '**powder-downs,**' well seen on the breast of herons and bitterns, also in tufts on more-pork (*Podargus*), rollers, and parrots. In these the sheath covering the barbs disintegrates into a powder, which consists of minute horny platelets. The suggestion of greasiness in the powder is a mechanical illusion, due to the very flexible nature of the minute fragments of horn. It has been supposed that the dust of the 'powder-downs'

[1] Or *rachis*.

may help to keep the other feathers in good order, but this is little more than a guess. The feathers occasionally occur all over the skin (in penguins), but they are usually disposed in regular rows (feather-tracts or *pterylae*), which show particular patterns in different types.

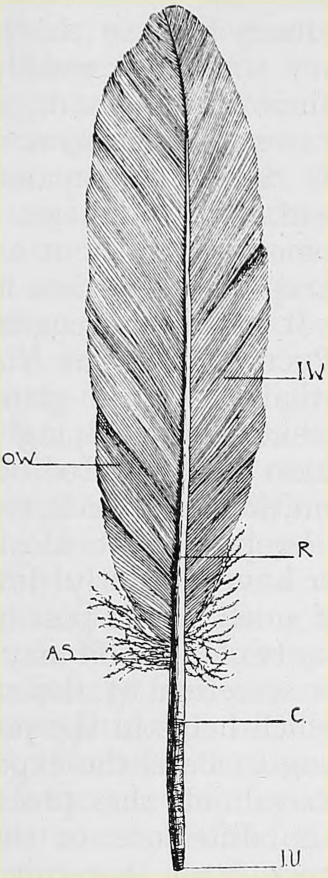


FIG. 224. A TYPICAL FEATHER

R, rhachis; IW, inner web of vane; OW, outer web of vane; AS, aftershaft; C, calamus or quill; IU, inferior umbilicus, where pulp enters.

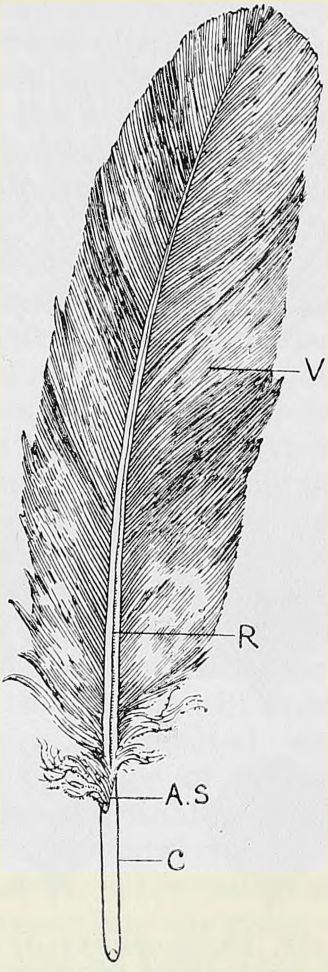


FIG. 225. SECONDARY FEATHER OF A PIGEON

C, calamus; AS, aftershaft; R, rhachis; V, vane.

This ' pterylosis,' as it is called, is of some use in classification. Here and there, on the skin, varying in size in different types, there are bare patches without any feather-follicles.

Apart from the occasional presence of glands near the ear-opening, the bird's skin has only the **preen-gland**; and even that may be absent, as in ostrich, emu, cassowary, bustard, some parrots, and the fantail pigeon. It is best developed in aquatic birds, and this may be associated with the need for waterproofing the plumage. Some mammals lick and brush their skin, but in the main the fur is kept in good order

automatically by the secretion of the sebaceous glands at the roots of the hairs. Birds, on the other hand, have to attend to the feathers individually, and they may be sometimes seen reaching back with their bill to the preen-gland, which produces an oily secretion. But some birds, like the scissorbill (*Rhynchops*), have bills so sharp-edged that they could not readily compress their preen-gland, and in many cases the secretion is very small in amount compared with the extent of the plumage. Moreover, some birds without a preen-gland keep their feathers in good order. It has been suggested by W. P. Pycraft in his fine *History of Birds*, that the preen-gland may be a scent-gland, helping in the recognition of kin. Its odour is musky in the musk-duck, repulsive in the hoopoe. But most birds seem to have a poorly developed sense of smell. It is possible that a drop or two of the oil may stimulate the secretion of the salivary juice, which helps in the preening. According to Paris the experimental removal of the preen-gland makes no difference to the bird. The structure of this enigmatical organ closely resembles that of the odoriferous glands of some reptiles; it is a bilobed subcutaneous mass of glandular tubes, supplied by blood-vessels and nerves, surrounded by a capsule of connective tissue, but without muscle-fibres except at the opening.

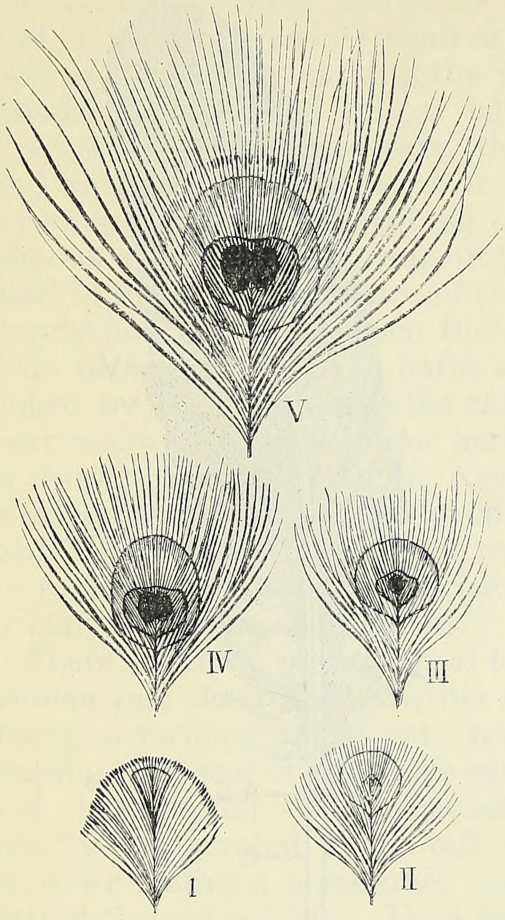


Fig. 226. Development of Tail-feather of Peacock

After a feather is fully formed, the component cells begin to die away, and the pulp retreats into the skin, leaving little partitions or ' caps ' across the interior of the quill. It follows that there can be no repair of worn feathers, and it is therefore advantageous that there should be **moulting.** To state the case in another way, a feather is a structure with a limited length of life, like a leaf on a tree; and there is a periodic dying away and reactivation in the feather-follicle. Moulting usually occurs after the fatigue of the breeding season and before the autumnal migration, but in some birds, e.g. swallows and hawks, it

occurs in midwinter. The process of shedding the old feathers and replacing them is usually spread over a considerable time, but it may be so rapid that the bird is left very naked. Thus moulting geese, ducks, and rails lose all their pinions at once, and are for a time unable to fly.

All birds moult, more or less completely, once a year, but some moult twice, e.g. the garden warbler. There is often a special spring moult, when the male birds put on their nuptial plumage. The ptarmigan has three moults in the year, the winter plumage being almost completely white. There are many other exceptional features; thus the penguins moult their feathers in patches, not individually. The physiology of moulting is very slightly known, but there is much interest in Beebe's experiments (1914) on the males of the scarlet tanager and the bobolink, in which a brilliant summer plumage normally alternates with a totally different winter garb. At midsummer the birds were placed in small cages in a quiet room, with gradually diminishing light and slightly increased food. They ceased to sing, put on fat, and increased in weight. Thus the modified environment brought about a bodily condition very different from the thinness and fatigue that normally follow the strain and the cares of the breeding season. The autumnal moulting time passed without a single feather being shed. Midwinter found the birds in their brilliant summer plumage. Early in spring some of them were gradually brought into normal conditions, whereupon the spring moult took place, the birds passing directly from one nuptial plumage to another. In every case the winter plumage, which should have been interpolated, was suppressed. Beebe's conclusion was that the condition of the birds as regards fatness or thinness determines whether they shall moult or not. Side-experiments showed that the seasonal ' pigmental changes in the blood ' go on as usual, for one of the tanagers, subjected to rapidly altered temperature, underwent a belated moult into the green winter plumage, which is probably the ancestral colour, being that of the young of both sexes and of the adult females. In the other tanagers scarlet feathers remained through the winter, and were succeeded by scarlet in the spring moult. Thus it is plain that the succession of plumages is not rigidly predetermined; there is a plastic correlation of internal constitutional rhythms and external seasonal periodicities.

When a pinna replaces a nestling down-feather, a residue of the down-feather foundation persists and proceeds to form its successor. In all other cases the new feather arises more indirectly. The *new germ arises on one side* from the base of the previous papilla while the old feather is still growing. This new feather-germ forms a process which grows into the deeper layers of the dermis and there forms a new papilla, developing into a feather. The old papilla dwindles away after the old feather falls off.

In connection with the variety of plumage, it is useful to bring together the chief **uses of feathers.** (1) The first use was probably to form a relatively non-conducting robe, tending to retain the animal heat. This may be aided by layers of air included between and below the feathers, and by occasional whiteness, so striking, for instance, in the snowy owl. (2) The plumage may also save the warm vascular skin from being wetted by rain and snow, or by the water in swimming and diving birds. This prevention of wetting varies in different birds, and it is interesting to observe the energy that the aquatic cormorant expends in drying itself. (3) The feathers make flight possible; and here may be noted the light elastic build, the resistance to wear and tear, the almost air-tight linkage seen in the vanes of the pinions, and the possibility of attaining great length without much weight. (4) The plumage often renders the bird very inconspicuous in its habitual surroundings. Thus the brooding woodcock among the fallen leaves and withered herbage has a very effective cloak of invisibility, and many a bird looks like a piece of scenery. Very common is the obliterative counter-shading seen in a bird like a curlew or a sandpiper, whose plumage is lighter below and slightly darker above, the two shades blending on the sides. This light-and-shade camouflaging is very common and very effective. But another type is seen in the irregular or ' dazzle ' pattern, where variety in different parts breaks up the shape of the body, a good example being the brightly coloured golden plover, which is very inconspicuous on the moor as long as it remains stationary. This type of protective coloration has the advantage of being effective against diverse backgrounds. Conspicuous white patches, as on the wheatear's rump, may help to distract the enemy's eye from more vulnerable parts. (5) Conveniently separable, perhaps, from protective coloration is that which masks aggressive birds, in the eyes of their victims, as may be the case with the Greenland falcon and the snowy owl. Here might be included other qualities of the plumage that are useful in the chase, such as the softness that makes the flight of owls so noiseless. (6) When there is a profitable resemblance to other birds, the term **mimicry** may be legitimately used, and there are a few cases of this among birds. A weak species may profit by being like a strong one, a predatory bird by being like a peaceful one. Alfred Russel Wallace pointed out that the friar-birds of the Malay Archipelago, large, strong, gregarious, assertive honey-eaters, holding their own against birds of prey, are ' mimicked ' by the weaker orioles, and that the particular species of friar-bird on each island has its corresponding mimetic oriole! Cuckoos probably succeed better when they are like hawks, as is sometimes the case. ' Of aggressive mimicry, a good example is the caracara of South America, a carrion-eating hawk which also catches small birds by stealth. It is

enabled to do so by its close superficial resemblance to a species of curassow, a harmless game-bird, which is common in the same region' (A. L. Thomson, 1927). (7) Feathers are often auxiliary to the appeals made in courtship. They may enhance the brilliance of the male bird; they may be exaggerated into extraordinary decorations, as in birds of paradise; they may form tufts and crests, erectile in excitement; they may be used to produce arresting sounds, as in the 'drumming' snipe. (8) In many cases, reaching a climax in eider-duck, feathers are used in nest-making, not only conserving the heat around the imperfectly warm-blooded nestlings, but also making the brooding more comfortable. (9) Finally, there are a number of minor uses, such as helping in the recognition of kin by kin. But the point is that the evolution of feathers—the most highly specialized of all integumentary structures—must be thought of in relation to many different utilities. In relation to these its variations or new departures have been selected throughout long ages.



FIG. 227. MALE AND FEMALE BIRD OF PARADISE

The male has highly decorative, brilliantly coloured plumage. That of the female is simple and relatively plain.

COLOURS OF FEATHERS.—Attentive observers begin to notice towards midsummer that their favourite gay birds, such as yellow-hammers and chaffinches, are not quite so fine as they were. This is due objectively to an actual loss of some of the best feathers, to an ebbing of the living matter from those that have reached their climax, and lastly, to wear and tear. As a feather reaches full size it ceases to be alive; and this change makes some difference in the absorption and reflection of the light-rays that fall on the intricate structure, and consequently to the colour. Moreover, we know that in some cases, before the feather dies away, there is a migration of pigment-containing cells into the skin. But most important is the simple fact

that friction destroys part of the microscopic surface structure and sub-surface structure, to which many feathers owe their particular sheen.

It may be recalled that coloration in animals is of three kinds: chemical or pigmentary, structural or physical, and a combination of the two (see ANIMAL PIGMENTS). So fine feathers depend partly on their structure and partly on their pigment.

The soberer colours of birds' feathers—from black through brown to grey—are due to pigments called **melanins**; and it is well known that these may arise by the action of a ferment (*tyrosinase*) on amino-acids, such as *tyrosin*,[1] which are always being produced by the breaking down of the proteins invariably associated with living matter or protoplasm. This is what may be called a satisfactory piece of information, since it enables us to understand how darkish pigment material is always available. Melanins always occur in the form of microscopic granules, and it seems almost certain that they are carried into the developing and growing feather by migrant pigment-carrying cells or *melanophores*. Investigators who have gone deeply into the matter tell us that the melanin granules are of direct use in the making of the feather, because they increase the strength and elasticity of the horn or *keratin* out of which the bird's plumage is composed. In a parallel way an admixture of sulphur changes india-rubber into vulcanite. It is very interesting to notice that the deposit of melanin is more abundant in the feather along lines of most strain, as in the simple case where the midrib or rhachis of the feather is black and the vane much lighter. Many a bird, such as the curlew, becomes darker as the summer months pass; and this is because the lighter margins of the feather get first worn away with use. *The parts with most melanin last longest.*

But many birds are adorned with yellow, orange, and red pigments, belonging to the series known as *lipochromes* or *chromolipoids*, chemically very different from the melanins, though the two kinds often occur together. As instances we may mention the red feathers of the flamingo, the scarlet ibis, and the cardinal bird; while most of our familiar black and brown birds, like the rook and blackbird, hedge-sparrow and lark, have melanins. The bio-chemical interest of lipochromes is that they have their counterpart in plants in the two chlorophyll-yellows which accompany the two chlorophyll-greens in making the green-complex of leaf pigment. The two common chlorophyll-yellows of plants are called *xanthophyll* and *carotin*; and it is interesting to notice that the former occurs in the yolk of the bird's egg and the latter in butter. Thus we can understand, in a vague

[1] Chemically known as para-hydroxyphenylalanine, $HO.C_6H_4.CH_2.CH(NH_2).COOH$.

way at least, how birds that eat parts of plants might get their lipochromes. Similarly, it is satisfactory, as we say, to have it proved that the *flavone* pigment of the marbled white butterfly is found in the cocksfoot grass on which the caterpillar feeds. Animate nature abounds in these reincarnations or re-embodiments.

More than half a century ago a naturalist in Africa noticed that one of the resplendent plantain-eaters or turacos looked rather washed-out after rain, and was amazed to find that his hand was stained when he stroked the bird's moist plumage. Several birds of this family show the same peculiarity. Their pigment, called *turacin*, is soluble in water that contains a trace of ammonia, as ordinary water frequently does; and it is practically identical with *uroporphyrin*, a pigment derived from the haemoglobin of the blood and present in minute quantities in normal urine. In the plumage of some plantain-eaters it produces a reddish to purple-violet coloration, and it is less unique than used to be supposed. It is interesting that the turaco colours the water of its bath, but more interesting is the suggestion that its pigment is a waste-product or degradation-product derived from the breaking down of the haemoglobin of the blood. Thus it would not be fanciful to say that the turaco's colouring illustrates 'beauty for ashes.' In this connection it may be recalled that the pigmentation of some butterflies' wings, e.g. sulphur-coloured yellows, is due to pigments related to uric acid—one of the commonest of waste-products.

Half of the charm of fine feathers is due to their physical texture, which allows of many gradations of colour while the pigment remains the same. Moreover, the metallic colour changes as the bird moves or as we move. The peacock's tail is perhaps the most dazzling expression of this. So the question arises: What is the physical structure that produces all this iridescence? The answer is, as usual, intricate in detail; but in a general way it may be said that there are three factors which operate separately or in combination. (1) In the first place, the surface of the barbs that make up the vane may be finely streaked or marked with alternate ups and downs, and so forth; and this affects the reflection of the light and thus produces colour. But this is certainly not the main factor, and the comparison of the surface of the feather to a fine grating has been for the most part given up. (2) Much more important is the fact that each little piece of a metallic feather shows that the horn has been formed in fine parallel zones or *laminae*. These are expressions of rhythmic growth, and their lines break up the light that falls on them. (3) Thirdly, microscopical examination also shows that in many cases there are in the barbs numerous little cavities filled with gas, and often divided up into many very minute canals. To this very delicate and intricate structure, which we may think of as a sort of

organic foam, the finest colours are due; and it will be understood that blues and greens may result though there is no blue or green pigment. The general impression one gets is that just as pigments are physiological by-products or waste-products, so the structural minutiae that cause refraction of the light are primarily the ripply marks of orderly and rhythmic growth. From these two readily intelligible data there have been evolved the subtle colorations that make for safety or for display, for warning or for attraction, as the case may be. Let us look again at that woodcock, that chaffinch, that hornbill, that bird of paradise!

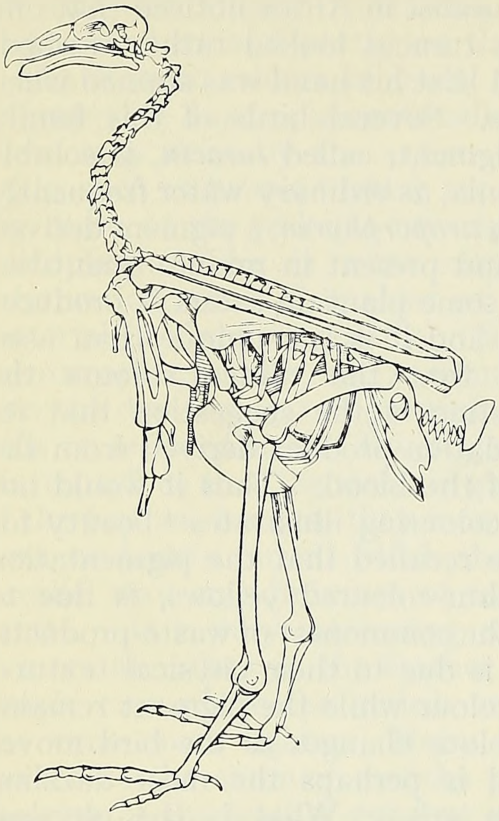


Fig. 228. Entire Skeleton of Condor, Showing Relative Positions of Chief Bones

SKELETAL ADAPTATIONS. — Instead of describing in order the different parts of the bird's skeleton, we shall give first place to its **adaptiveness.** Through and through it shows particular adjustments which make for efficiency, what are called adaptations or fitnesses. They are particularly conspicuous in the skeleton of birds because there are usually two different kinds of locomotion, running and flying, often with the addition of swimming; and skeletal adaptations are particularly concerned with locomotion.

(*a*) There is no doubt something peculiar in the process of bone-making in birds, as compared with that in mammals and other Vertebrates, but we can hardly, as yet, get beyond a simple acceptance of these peculiarities and an interpretation of them as making for efficiency. Thus we have to say, though it is only part of the story, that the skeleton of birds is 'lightly built,' and is thus adapted for flight. Being lightly built implies that the medullary cavities of the long bones are large, that they are often without marrow in adult life, that many of them contain air-cavities continuous with the lungs, and that they frequently show very spongy bony tissue below the hard and compact cortex. Thus the skeleton is built on the hollow girder principle, with a relatively large surface for the insertion of muscles, yet without the corresponding increase of weight that would be involved if the bones were as substantial as those of reptiles and mammals. Long

bones with large cavities also occur in bats and in *Pterodactyls*, but the 'pneumaticity' is never so pronounced as in birds. In some birds, such as the albatross, practically every bone is 'pneumatic' except the scapula and the hyoid; but to show that this structure does not in itself necessarily imply powerful flight, it is only necessary to mention the hornbill, one of the most pneumatic of birds, but a poor flier. In the case of the skull-bones, the air-cavities are in communication with the nasal chamber and auditory passage, not with the lungs as in the rest of the skeleton.

(*b*) A second general character of the bird's skeleton is the tendency that adjacent bones have to fuse together while still in the making. This also must depend on some constitutional peculiarity, and it occurs in many different parts of the body. Thus, except in running birds, most of the bones of the skull coalesce very early, which may be in some cases adaptive when the skull as a whole is used as an instrument, e.g. as a hammer when the woodpecker is excavating a hole, or for tearing up a victim in birds of prey. The fusion of most of the thoracic vertebrae in ordinary flying birds affords a firm fulcrum for the down-stroke of the wings. This interpretation is confirmed by the absence of fusion in running birds, and by the tendency to coalescence in the thoracic vertebrae of bats. The fusion of several vertebrae (thoracic, lumbar, and caudal) with the true sacrals, to form a *syn-sacrum*, and the fusion of this with the entire length of the iliac portion of the pelvic girdle, must be interpreted in adaptation to bipedal progression. So much of the bird's body is usually in front of a perpendicular dropped from the socket or **acetabulum**, with which the head of the thigh-bone or femur articulates, that it is necessary for effective balancing that the hip-girdle should take a long and strong grip of the backbone. The point is emphasized if the bird's hip-girdle be contrasted with that of the jumping and swimming frog, which cannot stand on its hind-legs,

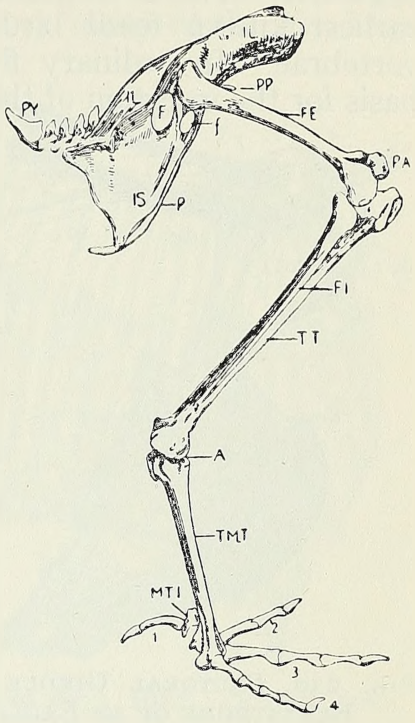


FIG. 229. PELVIC GIRDLE AND HIND-LIMB OF A FOWL

IL, ilium, fused to the syn-sacrum; IS, ischium; F, foramen; *f*, obturator foramen; P, posterior part of pubis, PP, pre-pubic process; PY, pygostyle; FE, femur; PA, patella; FI, incomplete fibula; TT, tibio-tarsus; A, inter-tarsal ankle-joint, without free ankle-bones; TMT, tarso-metatarsus; MT1, free metatarsal of 1, first, backward-turned, toe; 2, 3, 4, the other toes.

and has only a single sacral vertebra, with which the thigh-bone has merely a ligamental attachment. In all modern flying birds (*Carinatae*), though not in running birds (*Ratitae*), there is a fusion of about four terminal vertebrae to form the ploughshare-bone or **pygostyle.** This is in great contrast to the long lizard-like tail of the earliest known fossil bird—*Archaeopteryx*—which had twenty free vertebrae. In ordinary flying birds the ploughshare-bone forms a basis for the insertion of the tail-feathers or rectrices, and may thus be interpreted as adaptive. Reference will be made later to the fusions that occur in the regions of the wrist and palm, and in the region of the ankle and instep. In the running birds, where the pectoral girdle is unimportant, the scapula and the coracoid are fused into one bone and lie almost in one line.

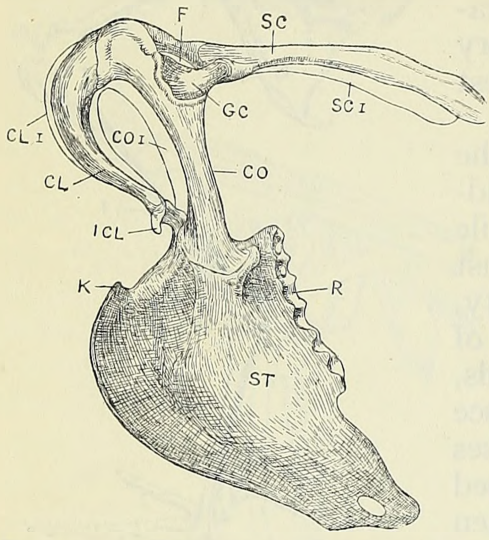


FIG. 230. PECTORAL GIRDLE AND BREASTBONE OF AN EAGLE

SC, scapula; F, foramen; GC, glenoid cavity; CO, CO1, coracoids; CL, CL1, clavicles; ICL, interclavicle; K, keel or carina of the sternum; ST, body of sternum; R, notches for insertion of ribs.

(*c*) Some of the other adaptations to flight may be dealt with more briefly. The **keel** or *carina* on the sternum serves for the insertion of the pectoral muscles, and its varying prominence in relation to the body of the sternum in different types stands in interesting correlation with the power of flight. A keel is slightly developed in bats and also in moles, both of which have strong pectoral muscles. It is naturally absent in *Ratitae,* which may never have had wings. It is degenerate in the rare burrowing parrot (*Stringops*) of New Zealand. It may be that Stringops suffered from a weakness of sternal development, and therefore became a burrower; though Lamarckians would read the story the other way round and say that Stringops lost its keel because it gave up flight in favour of burrowing. The case of penguins is interesting, for while they are flightless, they have a very strong keel; this fact becomes more intelligible when we recall the vigorous way in which they use their flipper-like wings in swimming and in scrambling on the snow. In contrasting the carinate and the ratite breastbones it is interesting to notice that the former is usually carried far back, forming a useful supporting floor for the viscera, of especial value in flying and swimming, whereas the latter is a broad shield, not carried backwards, the weight of the viscera being borne by the strongly developed thoracic and lumbar vertebrae, and by the backward extension of the rib framework.

The sabre-like scapula of flying birds is bound by ligaments to the ribs and to the backbone; the strong coracoid is braced movably in a deep groove on each side of the front of the breastbone; the springy clavicle extends crosswise in front of the heart, and has its middle piece attached by ligament or sometimes fused to the tip of the keel; except in the South American screamers (*Palamedeae*), many of the ribs have

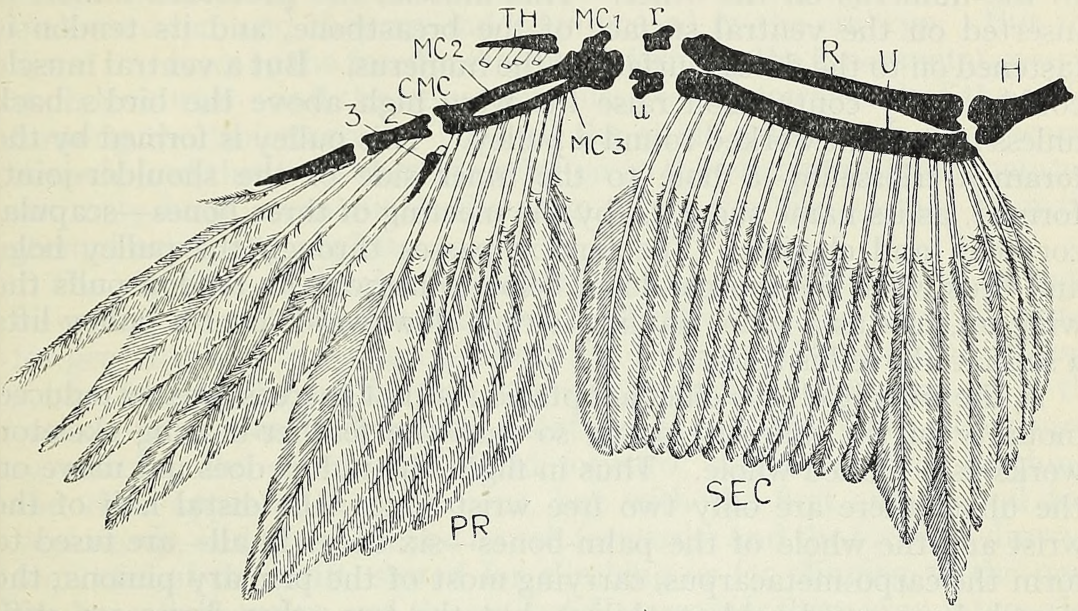


FIG. 231. DIAGRAM OF THE BONES OF THE WING OF A BIRD, AND OF THE CHIEF FEATHERS

H, humerus; R, radius in line with the thumb (TH); U, ulna, bearing the second largest feathers, the secondaries (SEC). The radius and ulna are quite free from one another. *r*, radiale; *u*, ulnare; MC1, MC2, MC3, metacarpals, fused with the distal carpals to form the carpo-metacarpus (CMC). PR, largest or primary feathers, carried by the carpo-metacarpus and by digits 2 and 3. The second finger (2) has two joints or phalanges; the third (3) has only one.

a backward-projecting uncinate process, which overlaps the rib behind, to which it is lashed by ligament, thus binding the rib-system into a kind of coherent basket; the lower or sternal parts of the ribs, which reach the breastbone, are bony, not gristly [cartilaginous] as in mammals. The total result is to form a coherent springy framework (of backbone, breastbone, ribs, and pectoral girdle) against which the wings can work with maximum efficiency. The arrangements prevent any incrushing on the heart during the down-stroke of the wings, yet the alteration in the capacity of the chest-cavity, as the breastbone is raised and the backbone depressed, facilitates the outrush of air from the lungs which are firmly fixed to the ribs. The glenoid cavity, formed by the junction of scapula and coracoid, is much more open

than in mammals, and is thus well suited for the free play of the wings. If the clavicles, forming the **merrythought,** are broken, the bird cannot fly. They are rudimentary or absent in running birds, and much reduced in some birds that do not fly much, e.g. certain parrots.

A simple but neat adaptation is seen in the way in which the muscle that raises the wing is related to the breastbone on the one hand and to the humerus on the other. This muscle, the pectoralis minor, is inserted on the ventral surface of the breastbone, and its tendon is fastened on to the dorsal surface of the humerus. But a ventral muscle could not by contraction raise the wing high above the bird's back unless its tendon worked round a pulley. This pulley is formed by the **foramen triosseum,** a hole to the inner side of the shoulder-joint, formed, as its name suggests, by the meeting of three bones—scapula, coracoid, and clavicle. The tendon passes through the pulley hole, and thus when the muscle down below contracts, its tendon pulls the wing up, just as a sailor hauling a rope downwards over a pulley lifts a sail far above his head.

In the **wing** itself the chief adaptation is that there is greatly reduced mobility in the different parts, so that the feather-bearing skeleton works as a unified whole. Thus in flight the radius does not move on the ulna; there are only two free wrist-bones; the distal half of the wrist and the whole of the palm-bones—six bones in all—are fused to form the carpo-metacarpus, carrying most of the primary pinions; the thumb has considerable mobility, but the two other digits are stiff. But while the fore-limb may be said to act *en bloc* in striking the air, the other side of the adaptation is the neat way in which it folds up in one plane into the resting position, forming a compressed letter Z, the elbow pointing backwards, the wrist joint forwards, the tips of the digits (probably 1, 2, and 3) backwards. This is a space-economizing arrangement, obviously very useful when the bird is swimming or diving with its feet, or threading its way afoot through thick herbage.

Among the adaptations to bipedal progression we have already noticed the syn-sacrum, which consists in a pigeon of one thoracic vertebra, five or six lumbars, two sacrals, and five caudals—a mere anatomical detail until the adaptive significance of the complex coalescence is appreciated. As we have mentioned, the fusion gives the hip-girdle a long and strong grip of the backbone, and thus facilitates the balancing of the body on the rounded head of the thigh-bone. The elongation of the different regions of the leg is well suited for rapid running, the most striking feature being the long, more or less vertical, tarso-metatarsus—a unique piece of skeleton. Except in the two-toed ostrich it consists of three coalesced metatarsals (or instep-bones), and to the upper end of these the distal ankle-bones or tarsals are fused. With the exception named, the lower end bears three articular knobs,

for the three toes. If there are four toes, as in fowls, the first is turned backwards, and has a small separate metatarsal of its own. The tarso-metatarsus adds to the bird's running power and swimming power, and in the divers and their relatives it is laterally compressed into a narrow blade, which reduces friction in preparing for a strike and concentrates the force in the region of the foot when the backward stroke is made. At the bird's ankle-joint two rows of small tarsal bones would naturally be looked for, and they are indeed indicated in the embryo. But the distal row fuses to the fused metatarsus, forming the tarso-metatarsus—six bones in all—and the upper row fuses to the lower end of the tibia, forming the tibio-tarsus. Thus all the ankle-bones have disappeared as such, and this, considered in relation to the elongated tarso-metatarsus, may be of mechanical advantage when the bird springs from the ground or rapidly alights.

The detailed skeletal adaptations of the toes are many; it must be enough to mention the very powerful talons of birds of prey, suited for gripping and carrying the booty; the elongated toes of the *Jacana*, suited for walking on floating leaves; the unusual arrangement in the cuckoo, the first and fourth pointing backwards (with the fourth reversible), the second and third forward, suited for firm perching; the same appearance in *Trogons*, but with the first and second toes backwards, and the third and fourth forwards; and the forward-directed four toes of the swift, suited for climbing or for clinging to the nest. In divers and grebes and the extinct *Hesperornis* there is an interesting prolongation of bone rising from the head of the tibia above the knee-joint. As a basis for strong muscles it gives much additional power to the swimming stroke. It is said to have arisen in three different ways!

Since the fore-limb with its hand has been given up to making a wing, there follows an assumption of new functions by the skull, which becomes a manifold instrument. Perhaps this is facilitated by the early fusion of most of the cranial bones in flying birds, and it is interesting to notice that somewhat similar fusion occurred in the unrelated *Pterodactyls*. The exaggeration of the premaxillae to form a beak is an obvious adaptation, and the absence of teeth in modern birds is compensated for by the horny bill.

The lower jaw consists of six bones on each side, a morphological point that reveals the affiliation of birds to reptiles, and indicates that they are anatomically far away from mammals, where the lower jaw is simple. Similarly, the lower jaw articulates with the quadrate in birds and reptiles, with the squamosal in mammals. More important, however, from our present point of view, is the loose articulation of the lower jaw with the movable quadrate, for this increases the gape—an important feature in various ways. Thus it facilitates rapid swallowing of large booty, and catching small insects in mid-air.

The importance of vision in birds is correlated with the large orbits, and these are correlated with the restriction of the cranial cavity to the posterior region of the skull, which is very markedly broadened out. One of the most striking advances of birds, as compared with reptiles, is in the proportion between the brain-containing region and the size of the skull as a whole. The skull has great mobility on its single occipital condyle (another reptilian feature); and here should be noted the mobility of the neck with its characteristic double-saddle-like or **heterocoelous** vertebrae. Looked at from in front, the body or centrum of the vertebra is concave from side to side, convex from above downwards. Looked at from behind, it is saddle-shaped, and the functional significance of this is that it affords great freedom of movement. The bill can reach the preen-gland; the head may be seen resting between the shoulder-blades with its point towards the tail. Even a little feature like the presence of numerous small cervical ribs has its functional interpretation, for they afford insertion for the much developed neck-moving muscles. The bird's skeleton is a bundle of adaptations.

Flight of Birds

The problem of flight has been solved (1) by insects, in which the rapidly vibrating wings are flattened outgrowths of the dorso-lateral body-wall of the meso- and meta-thorax, worked by strong muscles at their base; (2) by the extinct flying-dragons or *Pterodactyls* (q.v.), in which a fold of skin was extended on the greatly elongated outermost or fourth finger; (3) by birds, in which the transformed fore-limb owes its striking surface mainly to the feathers; and (4) by bats, in which a fold of skin, beginning at the neck, is continued along the anterior surface of the arm, then between the greatly elongated fingers and palm-bones, and onwards along the sides of the body to the hind-legs, and to the tail if that is developed. The four solutions are obviously on quite different lines.

It is highly probable that birds were given to swift running before they were able to fly, and that the beginnings of flight were long flying leaps which sometimes landed them in low trees. It is likely that they practised **parachuting** from tree to tree, as some reptiles, like *Draco volans* (see Fig. 217), still do, before there was much in the way of true flight. The existence of a slight web or **patagium** in front of the bird's wing may be recalled. It is likely that there was a prolonged arboreal apprenticeship, which is pointed to, for instance, by the gripping arrangements of the toes of birds, and also by the active climbing of the young of the primitive hoatzin (*Opisthocomus*), which uses its clawed hands as well as its feet in moving about from branch to branch (see Fig. 232).

In **ordinary flight** the wings combine the functions of propellers and planes. From a raised position, sometimes vertically above the bird's back, they are pulled forwards, downwards, and backwards by the contraction of the largest pectoral muscle, and then raised again by the pectoralis minor, whose tendon works through a pulley at the shoulder-joint. The tip of the wing describes a curve somewhat like an asymmetrical figure eight. The downward component of the wing-stroke, displacing a mass of air, keeps the bird up or raises it; the backward component gives it horizontal velocity; but the resistance of the air, which tends to retard the forward movement, has an important lifting function, for it works upwards against the ventral surface of the body and the slightly concave under-surface of the wings. Between successive strokes there is bound to be some loss of altitude and momentum, but this is usually almost inappreciable. It is lessened by economizing energy in raising the wing. This is effected by an automatic reduction in the size of the wing when it is not pressing down against the air, by a movement of the individual feathers so that air passes between them, and by the convex upper-surface which allows the air to glide off easily. For physical reasons an increase in the rapidity of flight up to a certain limit lessens the proportion of energy required; it is relatively more economical to fly quickly. Marey calculated that the energy expended by a pigeon when first taking flight is five times as great as when it has acquired a certain velocity.

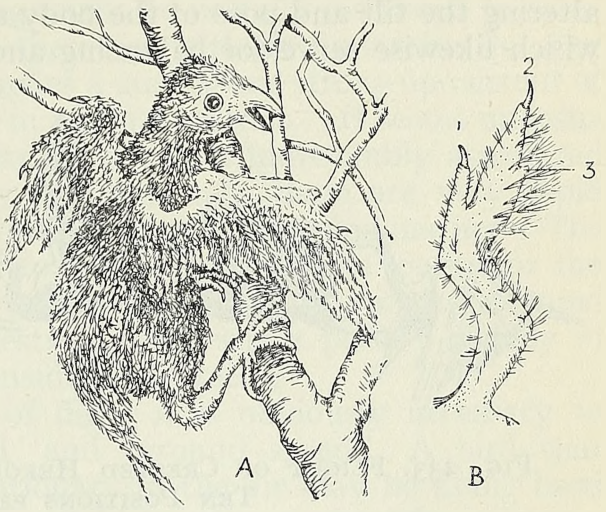


FIG. 232. HOATZIN (*Opisthocomus*)
The thumb of the young of this South American bird is clawed, as is also the first finger (diagram B). The claws are used in climbing from branch to branch (diagram A).

Among the most important **adaptations to flight** are: the shape of the body and the external reduction of frictional resistance; the light build of the skeleton, which affords large surface for the insertion of muscles and feathers without great increase of weight; the insertion of the wings high up on the thorax and the ballasting of the body with the heavier organs, such as liver and gizzard, below, so that the centre of gravity is far below the centre of suspension; the strong development of the pectoral muscles and of the keel on which they are ventrally inserted; the possibility of increasing the 'sail area,'

by lengthening the feathers, without necessarily involving much corresponding increase in weight or size of skeleton.

The secondary feathers, attached to the ulna, are of major importance in the wing-stroke; the somewhat longer primary feathers, attached to the hand, are of great use in lateral steering, hence their prominence in the insect-catching swallows and swifts. Steering is effected mainly by the differential action of the wings, but also by altering the tilt and pose of the body and by moving the tail-feathers, which likewise serve for balancing and as a brake. A quickly flying

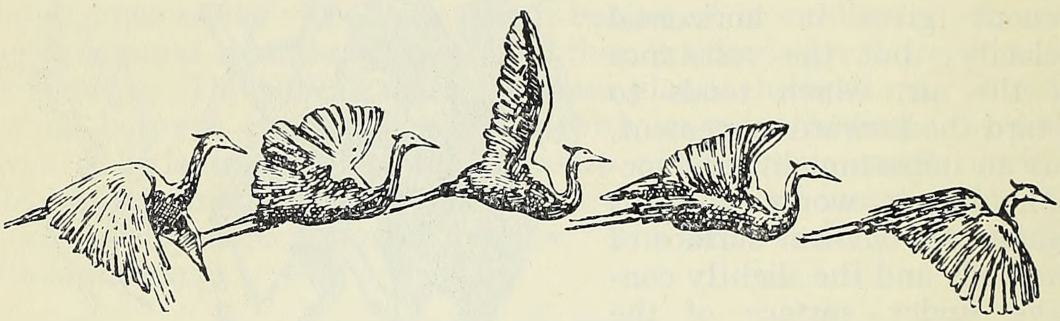


Fig. 233. Flight of Crested Heron, Depicted at the Rate of Ten Positions per Second

In the central position the wings are vertically above the back. They move forwards, downwards, backwards (first bird to left), and then up again.

insect like a bee may have 200–300 strokes per second; in its ordinary flight a sparrow has 13, a wild duck 9, a carrion-crow 3–4, a stork 2, and a pelican $1\frac{1}{6}$—a very noteworthy difference.

Besides ordinary flight there is **gliding**, when the bird having attained to a certain velocity ' rests on its oars ' for a while; or having attained a certain height descends to the ground without any stroke of its wings. It is probably the most primitive mode of aërial locomotion, parachuting rather than flying. A gull or a heron or any bird with a large sail area, having attained a certain velocity, planes with motionless wings, ' like an aeroplane with its engines shut off,' getting the necessary ' lift ' from the air-resistance to its forward movement; but this cannot continue long without loss of position, unless there is a strong up-current of air, as from the face of a sea cliff. Guidance during gliding may be effected by movements of the tail, head, and neck, and by tilting the outstretched wings. It would be convenient to use the term gliding for everyday exhibitions such as gulls illustrate, or the pigeon launching itself from the dovecote to the ground, or the hawk swooping from mid-air on its victim, and, if it misses, gliding up again without effort to a considerable height. Then the term **sailing** might be conveniently retained for extraordinary

exhibitions such as the circling of the albatross around the sailing-ship. The peculiarity in this case is that the bird sails with and against the wind without visible wing-strokes for perhaps half an hour at a time. It takes advantage of currents of air of unequal velocity at different heights. It glides down the wind, with increasing velocity, but sinking a little; it wheels and rises into a less rapid current, with reduced flight-velocity, changing part of its energy of motion into energy of position. The term **spiral sailing** might be usefully restricted to cases like vultures and storks, when they rise without up-strokes in slow spirals to a great height. It implies a steady and strong up-current of air, and is most frequently seen in warm countries. It seems undesirable to continue to call this **soaring**, which is indissolubly associated with the lark climbing the sky. In this case there are very rapid wing-strokes, with the downward component predominating. The soaring of the lark comes close to the **hovering** of the kestrel or the humming-bird, in which the very rapid beating of the wings is devoted to keeping the bird up. In kestrels and terns a perfect display of hovering seems to require a considerable breeze.

In thinking of the velocity of flight it is obviously necessary to distinguish between 'air speed' and 'ground speed.' A bird that seems to the observer to be stationary in the air may be flying hard against the wind. 'A bird flying at thirty miles per hour in a twenty-mile wind will seem from the ground to be making either fifty or ten miles per hour according to whether it flies with or against the wind' (A. L. Thomson, 1927). The most accurate measurements are those made from aeroplanes on birds keeping level with the machine, and flying in the same direction. Thus measured by Meinertzhagen, small song-birds show an average rate of 20–37 miles per hour, crows 31–45, ducks 44–59, plovers 40–51; but these may be increased in exceptional circumstances, and an occasional rate of 100 miles an hour is quite credible. 'Swifts of our common species, feeding 6,000 feet above Mosul, were noted as easily passing and recircling about an aeroplane which was registering sixty-eight miles an hour' (A. L. Thomson, 1926). We return to this subject later (p. 554).

The value of flight is obvious, but it may be useful to recall some of the different ways in which it has justified itself in the struggle for existence. 'It gave its possessors a new safety and independence; it enabled them to follow their food and to seek for water over long distances; it enabled them to secure the well-being of their offspring by building nests in well-concealed places, often inaccessible except to enemies who could also fly. More than that, the power of flight in its high development gave birds a unique power of annihilating distance, of evading the winter, of having two summers in the year, of having two homes, of changing their season in a night. In seeking

out suitable feeding-places and breeding-places neither space nor time presents any obstacle to the flying bird ' (Thomson, 1923).

THE FLIGHT OF SEA BIRDS.—One of the familiar sights on Scottish coasts is the diving of the **solan goose** or **gannet**, so well represented on Ailsa Craig and the Bass Rock. Its flight is as masterly as its diving, and well deserves the admiration it receives. As regards flight the solan goose should be grouped with the albatross, for in both cases the method called **sailing** is conspicuous.

What one usually sees is something like this. The solan goose, having just swallowed a fish, rises from the water, which must be a great effort—the first step which costs, as the French say. With powerful strokes of its long pointed wings, sometimes six feet in span, it rises gradually and not very quickly against the wind. The more wind there is the sooner the bird ceases to beat the air. It shortens its neck, shunting the centre of gravity well back, it spreads out its tail, it holds its wings like a great obtuse letter V and with the outermost parts tilted sharply upwards. The bird sails upwards in the eye of the wind, gaining energy of position and losing energy of translation. It reaches an altitude which depends (*a*) on the original momentum gained by the strokes, (*b*) on the force of the wind, and (*c*) on the position of the shoal of herring in the water below. It is often a hundred feet up, but it may be more than twice as much. If there is no shoal visible, the bird turns and, altering its attitude in the air, sails with the wind, losing some energy of position, but not necessarily very much, and often gaining greatly in speed. This speed is utilized again if the bird turns and sails upwards once more against the wind. We see this singularly beautiful alternation as the bird shifts from place to place, or retraverses its beat, searching the water with keen scrutiny. But if from its maximum height the bird discerns its booty, it lengthens out its neck, bringing the centre of gravity forwards, turns on its axis, planes downwards with half-closed wings, attains a great velocity, closes its wings, enters the water with a splash, and completely disappears. We have never seen any fish in the bird's mouth, but we do not know at what stage under water the swallowing occurs. The reappearance is sometimes at the place where the bird entered the water, sometimes at a short distance off. And so *da capo*; except that we often see the bird turn again and enter the water from a few feet above the surface. Altogether it is a fine performance.

In the same flight-group as the solan goose there should perhaps be ranked the **storm petrel** or Mother Carey's chicken. This small web-footed bird, which has conquered the open sea and never comes to land except to lay its egg and rear its offspring, agrees with the solan goose in the dominance of **sailing**. It usually keeps close to the water, often

with its long legs dangling and its feet pattering, but we may see a likeness to the solan goose in the rather deliberate strokes of the long wings and in the continual recurrence of resting on its oars and utilizing the horizontal gusts of wind. It is interesting to notice that while the storm petrel has a weight much less than a hundredth of the gannet's, the ratio of wing-surface to weight in the dwarf is six times greater than the same ratio in the giant.

The most impressive of the marine ' sailing ' birds is of course the **albatross,** which, as Froude says, ' wheels in circles round and round, and for ever round the ship—now far behind, now sweeping past in a long rapid curve, like a perfect skater on a perfect field of ice. There is no effort; watch as closely as you will, you will rarely see, or never see, a stroke of the mighty pinions.' In a general way, as we have already seen, the ' sailing ' bird utilizes air-currents, especially those that blow more or less horizontally. After getting some way on by vigorous wing-strokes, the bird sails upward against the wind, with most success when there is an accelerating gust; its wings are no longer striking, but they are adjusted every moment as nicely as the sails on a racing yacht, though in a different way; altitude is gained as velocity is lost; and then the bird veers and begins to sail with the wind, changing energy of position into energy of translation, and, with the help of the breeze, getting up a great velocity, which is once more utilized in another great ellipse or another turn of the spiral ascent in mid-air.

Along with the ' sailing ' web-footed birds Magnan ranks the **great shearwater** of the North Atlantic and the Mediterranean, and also the better-known **great black-backed gull,** a predatory giant over two feet in length, which we often see at a great height moving easily like a sloop before the wind. But the other gulls, such as the herring-gull and the kittiwake, are good examples of a second group, which we venture to call **stroke-gliders.** The distinctive feature here is that wing-strokes are frequent, though not of great velocity, and that they are followed by gliding or vol-planing, in which slight or moderate ascending or horizontal currents may be utilized. We often see a herring-gull flying from inland with leisurely but powerful wing-strokes, three or four in a second; as it reaches the escarpment of the shore cliffs it meets a breeze from the sea; it 'rests on its oars' and glides onwards for a long distance without further strokes. Then it begins again to strike the air. But even when there is no perceptible breeze we see the bird get up a certain momentum and then glide onwards with taut wings. This is ' gliding ' in the strict sense as distinguished from ' sailing,' but we do not pretend that in actual bird-life a hard-and-fast line can be drawn between them.

Every one has admired the very beautiful flight of the **terns** or sea-swallows, which look like miniature gulls, but have longer and more

pointed wings and a forked tail. In essentials the tern's flight is like that of an ordinary gull, but more rapid and unexpected, and after striking and gliding and striking again there is often a poising in the air, a rapid descent, and a splash into the water with wings half-closed. In many cases the tern's body is not submerged, but the amount of dive varies with circumstances and with the species. The shag, the cormorant, and the Manx shearwater should be ranked with the gulls and terns as 'stroke-gliders.'

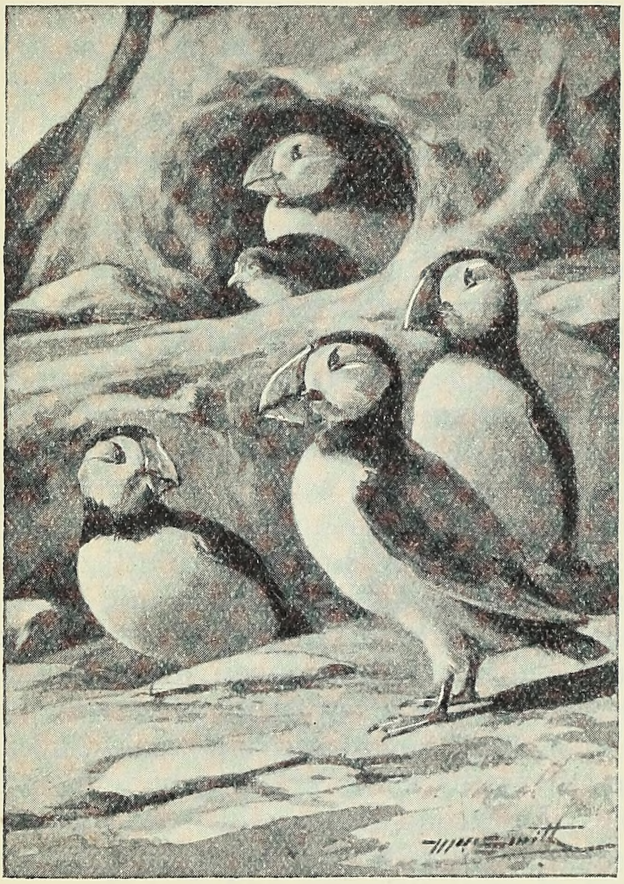


Fig. 234. Puffins.

A third and very distinct group includes the guillemots, the razorbills, the little auk, the puffin, the merganser, and the true divers. The distinctive feature here is the great reduction of the wing and the rapidity of the beats. There is no 'sailing' or 'gliding,' only a rapid beating of the air—so rapid that we speak of their **'whirring'** flight. A speed of twenty-five miles an hour is easily attained by some of these birds, but this is not usually sustained for more than a short distance. They whirr past, but they soon sink into the water again; and the broad fact is that the members of this group are more thoroughly adapted to swimming and diving than to prolonged flight.

A fourth group of sea birds, classified as regards flight, includes the marine ducks of all sorts, not forgetting scaups and scoters. The members of this group are distinguished by their rapid flight, often rising to over a mile a minute, by their well-developed wings, by the quick succession of energetic strokes (five to twelve per second), and by the extreme rarity of 'gliding.'

To sum up, we recognize that, apart from the soaring of the lark, the hovering of the kestrel, and other exceptional forms, there are **three main modes of flight.** There is the ordinary striking of the air,

during which the upright wings are brought forwards, downwards, slightly backwards, and then upwards again. There is 'gliding,' when the bird rests on its oars, having gained a certain momentum by energetic wing-strokes or by descending from a height towards the ground. Thirdly, there is the more mysterious 'sailing,' which reaches its climax in albatross and vulture. What we have tried is simply to group the more or less familiar sea birds in reference to the method of flight that is dominant. The subject has obvious practical as well as biological interest.

THE SPEED OF FLYING BIRDS.—A popular impression of the speed of a flying bird is hinted at in the well-known saying of Sir Boyle Roche that, not being a bird, he could not be in two places at once. But even in more modern and scientific estimates of velocity there has been considerable exaggeration. Thus it was a very insecure assumption that led Gätke, of Heligoland, to conclude that the Arctic blue-throat leaving Africa in the evening reaches Heligoland next morning, having traversed over 1,600 miles in 9 hours, that is to say, at the rate of 170 miles an hour. There is as little warrant for saying that the American golden plover makes its migratory journey from Labrador to Brazil, say 3,000 miles, in 15 hours, that is, at a rate of 200 miles an hour. There can be no doubt that those estimates are far too high.

From a rowing-boat in the middle of a strait it is sometimes possible to watch with some precision how long a big bird like a heron takes to cross, and this sometimes works out at thirty or forty miles an hour; occasionally, with the wind, at a mile in a minute. In an inland glen we have often watched gulls flying home to the coast in the evening, and when an estimate is made of the time required to pass from overhead to beyond a sharp bend in the valley, the gull's velocity can be calculated and checked many times. Our estimate is that thirty miles an hour is quite common. This is rapid when compared with the meditative (though purposeful) march of a tortoise, very rapid when compared with the crawling of a snail. It is almost instantaneous compared with a primeval mover like an amoeba, which rolls along at the rate of 600 microns (p. 571) a minute, which we take to mean that it would require nearly three-quarters of an hour to traverse an inch.

In *Problems of Bird Migration* (1926), by Dr. A. Landsborough Thomson, a critical position in regard to the velocity of flight is defended fair-mindedly. Thienemann's careful observations on birds in their autumnal migration give the following figures, leaving out the fractions, for miles per hour: hooded crow, 31; jackdaw, 38; starling, 46; finch, 32; crossbill, 37. These were averages for the time taken to traverse a measured length, and they were corrected for the influence

of the wind. As previously mentioned, Meinertzhagen made numerous careful observations from aeroplanes during the war, and he got pilots of the Royal Air Force to observe the speed indicators of their machines while keeping level with birds flying near and in the same direction. Some figures giving these true ' air speeds ' are: stork, 48; mallard, 50; rook, 45; gannet, 48; goose, 56; and lapwing, 45 miles per hour. ' Golden plover, when pressed by a pursuing aeroplane, accomplished 60 m.p.h.; swifts feeding at a height of 6,000 feet above Mosul easily passed and circled round an aeroplane doing 68 m.p.h.; and a lämmergeier made 110 m.p.h. while "nose-diving" to escape an aeroplane.' Meinertzhagen noticed that many birds 'press their accelerator' when pursued or pursuing, but he came to the conclusion, which everyday observation confirms, that it is the ordinary, not the accelerated, speed that is used in migration. Many of his figures are in the neighbourhood of 45 miles an hour; he gives 31–45 for crows, 38–49 for starlings, 20–37 for small perchers, 40–48 for falcons, 42–55 for geese, 44–59 for ducks, 40–51 for most waders. These data have all been verified many times, and they should serve to dismiss for ever the generous exaggerations of Gätke, and to displace the mistaken estimates that have been made by the uncritical observers of the performances of homing pigeons and the like.

Another detailed study (1926) of bird-migration by Horst Wachs, of Rostock, leads to similar conclusions. The time taken by an individual bird to return home is fallacious unless one knows that the bird was flying all the time. A marked gull took ninety minutes to cover some ten miles, but a gull can do much better than that. A swallow returned from about twenty miles in two hours and a half, but a swallow can do much better than that! On the other hand, when Gätke timed the plovers and curlews flying between Heligoland and an oyster-bed 22,000 feet to the eastward, and found that they only took a minute (which means flying at the rate of 250 miles an hour), he was measuring speed with the accelerator pressed hard down. We suspect, moreover, that there was something wrong with his stop-watch.

One reliable method is that followed by Thienemann, who arranged for two observers about a third of a mile apart and connected by telephone. They watched how long certain birds flying past took to traverse the distance between the two limits. A common result was thirty to forty miles an hour. The other reliable method is that of the various ornithological airmen who compared the flight of birds with their own for a number of consecutive minutes. The results reached by Thienemann and by the airmen show satisfactory agreement.

It must not be assumed that a bird which flies at the rate of fifty miles an hour can keep that up for many hours on end. On the contrary, as has been well shown by von Lucanus, birds often take a rest

after they have journeyed for a fair distance. A stork flying south does a good day's work when it covers 125 miles, but it need not fly without interruption; and it does not usually exert itself for more than six hours in the day. Yet this fact has again to be taken along with others, as Wachs points out, for there is no opportunity for rests when land birds are crossing a great stretch of sea, such as the Gulf of Mexico or the wastes between Alaska and the Hawaiian Islands. In some cases we must credit the birds with a consecutive flight of at least twelve hours. It comes to this—that one is safe in crediting many a bird with a velocity of forty miles an hour. The speed will be nearly halved against the wind, and sometimes increased by a quarter or more with the wind.

To be remembered also is the physical fact that the frictional resistance the bird has to overcome in the air is relatively slight, compared, for instance, with the frictional resistance of the water to a ship on the sea; and that when a bird has got thoroughly going, the tendency to sink is counteracted by the horizontal velocity. The faster the bird flies, the less work it has to do in keeping itself up; for the supporting force, which is the thrust upwards on the wings and body, increases with the square of the velocity. But we are not depreciating the flight of the Pacific golden plover from Hawaii to Alaska and back again. It is still ' too wonderful for us.'

ALTITUDE OF FLIGHT.—It is difficult to explain the persistence of man's tendency to exaggeration—an anachronism in a scientific age! If we see a thousand gulls we say five thousand. If a bird flies past at a rate of a mile a minute, we say a hundred miles an hour. Part of the reason is that we feel bound to produce in the mind of our audience a feeling of amazement, and so we multiply our numbers, knowing full well all the time that a wonder is qualitative not quantitative.

The ornithologist Gätke, who watched migrant birds for many years in Heligoland, and made numerous valuable observations, is to a large extent responsible for the exaggerated estimates of the altitude, as well as of the velocity, of birds' flight that have become current. He pictured migrants flying at a height of 20,000 feet or even more. He went the length of saying that he had seen a sparrow-hawk at a height of 10,000 feet and a rook at 15,000, whereas we know that birds of that size become invisible long before these heights are reached. Modern precision has punctured Gätke's over-estimates.

Gätke was influenced subconsciously by what he thought migrant birds *should* do—a way of looking at things that is always detrimental to scientific precision. He thought—rightly in this case—that flight would be much easier at great altitudes, therefore birds fly high. He thought that they needed to fly at a great height in order to see the lie

of the land. But in most parts of Europe, Asia, and Africa an altitude of 5,000 feet would be quite sufficient for outlook, and Gätke himself was well aware that some birds, like hooded crows, starlings, and larks, migrate very successfully, though they do not rise high above the ground or the waves. The Adélie penguins find their way from afar across the pathless sea, although they are, of course, confined to swimming. We are not asserting that it is impossible for a rook to fly at a level of 15,000 feet, for some mountain birds live for many months at this height above sea-level, and migrants have habitually to cross the Alps at over 11,000 feet, or the Himalayas at 18,000 feet, above sea-level; but the facts are entirely against the conclusion that high flying is at all common. When we speak here of altitude we mean above the ground, unless we specify 'above sea-level.' In the case of a bird like the condor there is high flying in both senses.

Airmen have furnished most of the facts which form the basis of modern estimates of the altitude of migratory flight; and the general conclusion stands firm that very few birds fly at a height of over 3,000 feet above the ground, and that most do not attain to more than half that height. Thus Meinertzhagen, amongst a large number of observations, had only thirty-six records over 5,000 feet. Seven of these were over 8,500 feet, a height observed for lapwings. One of the highest records was for cranes, which were seen at the great altitude of 15,000 feet. When an airman says that he saw a bird at 'a great height,' he means over 2,000–3,000 feet; and it is safe to say that most birds migrate at a much lower level. The idea that they vanish when they see the aeroplane approaching is said to be another of those inferences based not on fact, but on our idea of the way in which birds *ought* to behave.

There is another method of determining altitude of flight, used especially by Dr. von Lucanus. Migrants can be seen flying at 'a great height,' and with or without the help of a field-glass they can be identified. But by direct experiment it is not difficult to discover at what height a known bird will be visible to the observer, and at what height it will cease to be visible. Thus von Lucanus found that a sparrow-hawk was distinguishable at 800 feet, was a mere spot at 2,100, and disappeared from vision at 2,800 feet. The corresponding figures for a rook were 1,000, 2,600, and 3,300 feet. While Gätke believed that most migrant birds fly at a level beyond our range of vision, and that those we observe are the exceptions which have *come down*, von Lucanus concludes that most birds migrate within the range of our vision, and that those which the airmen report from over 3,000 feet are rare exceptions which have *gone up*. When we see cranes, wild geese, or storks migrating at a level where they are clearly recognizable in mid-air, their altitude is not over 3,000 feet, and this must be regarded as

exceptionally high. Yet we must avoid swinging to the extreme of denying the possibility of occasional flight at a much higher altitude, since this has been actually observed by airmen.

Whereas Gätke realized that flight would become mechanically easier as the birds got further from the earth, modern experience leads one rather to lay emphasis on the difficulties. Experiments made with birds taken up in balloons or the like to great heights show that they become very uncomfortable, to say the least; but perhaps these experiments should be revised. It would be well to experiment with birds that were normally in the way of flying high, and to take very precise account of other external conditions beside altitude. The main difficulties in the way of high flying are three—the reduced supply of oxygen in the rarer air, the frequency of strong wind, and the great cold. These difficulties are enough in most cases to keep the migrant birds—supremely emancipated as they are—from rising too high above the earth which is their racial and their individual cradle.

PECULIARITIES OF PENGUINS.—These Antarctic birds are bundles of peculiarities. (1) They are **flightless,** their wings being turned into somewhat scimitar-shaped flippers, covered with minute closely appressed feathers, which should never be called 'scale-like.' The whole flipper moves in one piece. (2) In flightless 'running birds,' namely ostrich, rhea, emu, cassowary, and kiwi, the breastbone is without a keel, the collar-bones are small or absent, and the coracoid is fused to the scapula—these peculiarities having to do with the fact that the wings are not used. But the penguin's breastbone has a very strong keel, for the insertion of muscles; the collar-bones are strongly developed like our own; the coracoid is at a sharp angle to the scapula and quite free from it. In fact the penguin's breastbone and breast-girdle (or pectoral girdle) might be compared to an eagle's! How is this to be explained? The answer is to be found in the fact that although penguins are flightless, they use their transformed wings in swimming and diving and even clambering on the hard snow. They also use their wings in giving one another great whacks, sometimes drawing blood when rival cocks fight furiously.

Another peculiarity is the moulting of the feathers in large coalesced patches. This is not to be compared with the '*sloughing*' of some reptiles, such as snakes, for what is cast in reptiles is the outermost layer of epidermis, covering the scales, whereas a bird casts its entire feathers, each of them comparable to a scale. But it is possible that the patchy moulting of the penguin's plumage is primitive.

On some of the shores of the Antarctic continent there are enormous rookeries of penguins, those at Cape Adare being estimated at three-quarters of a million. The nests are peculiar in being usually made of rounded stones which the cock collects, stealing them if he can. Some-

times the nesting-place of the Adélie penguins is on a cliff, and the parents have a climb of about two hours from the sea. When the feeding of the young birds begins, the parents have a busy time carrying up enormous cropfuls of prawn-like crustaceans. The chicks feed, like young cormorants, by thrusting their heads into their parents' gullet. In some species there is a unique peculiarity—a fold of

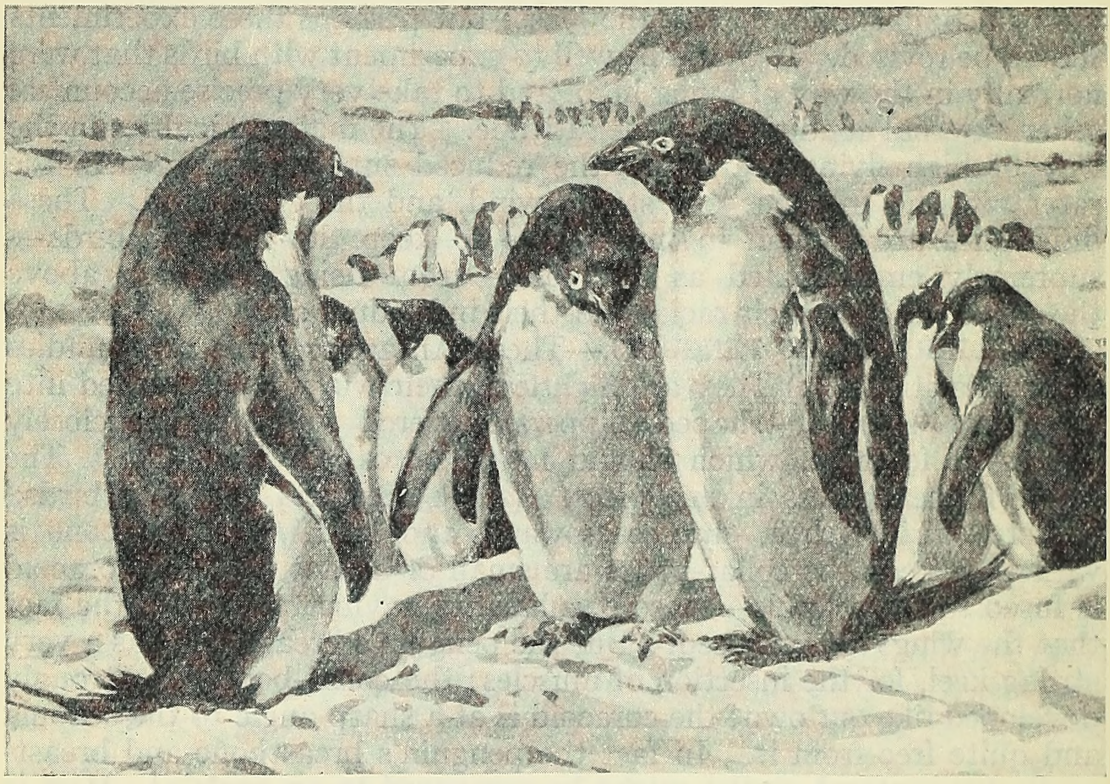


Fig. 235. Black-throated Penguins

feathered skin on the under-surface, just above the strong feet, forms a rough-and-ready pouch in which the eggs and the young one may be sheltered and kept off the wet.

Another peculiarity is the persistence of a kind of playfulness among the adults. Dr. Levick tells us in his *Natural History of the Adélie Penguin* (1915) that a favourite game was to board an ice-floe till it would hold no more, and get carried by the tide to the lower end of the rookery, where every bird would suddenly jump off and swim back against the current to catch a fresh floe and get another ride down. To find time for all this fun without leaving the chicks to perish, the penguins have devised the plan of ' pooling their offspring,' leaving them in charge of those who like mothering. Now and then, however, the parents bring in food to the *crèche*.

Brain, Senses, and Behaviour

The nervous system in Birds and in all typical Vertebrates consists of the brain, the spinal cord, the nerves given off from both, and the sympathetic nervous system. The sense-organs may be conveniently included.

BRAIN.—In many reptiles, such as crocodiles, the brain is almost ludicrously small in proportion to the size of the skull. It has not yet come to its own. But in birds it fills a spacious cranial cavity. It

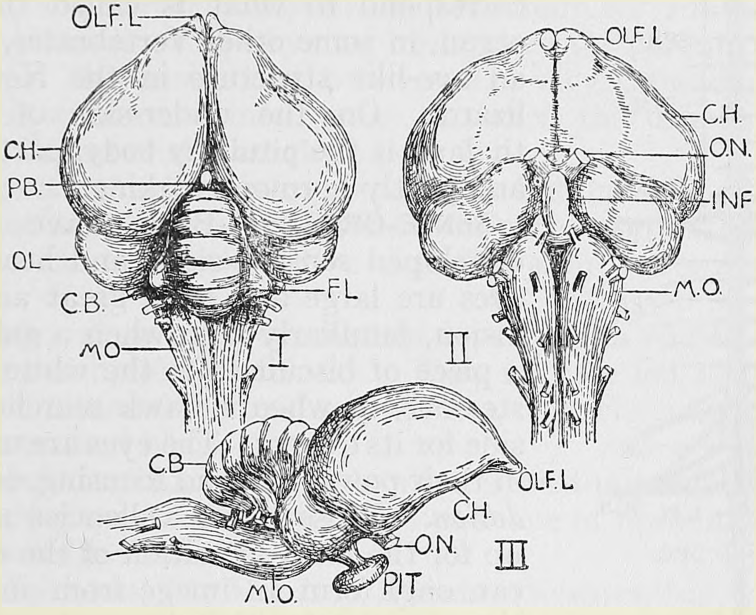


Fig. 236. Brain of Pigeon

(I, dorsal; II, ventral; III, lateral aspects)

OLF.L, olfactory lobes; CH, cerebral hemispheres; PB, pineal body; OL, optic lobes; CB, cerebellum; FL, flocculus or lateral extension of cerebellum; MO, medulla oblongata; PIT, pituitary body at end of infundibulum (INF); ON, optic nerves crossing in the optic chiasma.

shows: (1) two large smooth **cerebral hemispheres,** i.e. the *cerebrum*, the seat of the higher mental functions; (2) a hidden 'tween-brain (consisting of two **optic thalami**), which gives off nerves to the eyes and the *pineal body*; (3) the **optic lobes,** which are thrust to each side; (4) the large **cerebellum,** transversely ridged, which has to do with the control of movements; and (5) the **medulla oblongata,** which gives off most of the cranial nerves. The brain of a fish is in one plane, and one can see all the five parts at once, best of all in gristly fishes like the skate, but in birds it is curved upon itself through inequalities of growth, so that when one looks down on it one sees only the cerebrum and the cerebellum.

The **spinal cord** gives off numerous paired nerves, which have to do

with most of the reflex actions of the bird. The **sympathetic nervous system** forms a chain of nerve-centres or ganglia near the spinal cord on each side, and gives off nerves to adjacent blood-vessels and viscera.

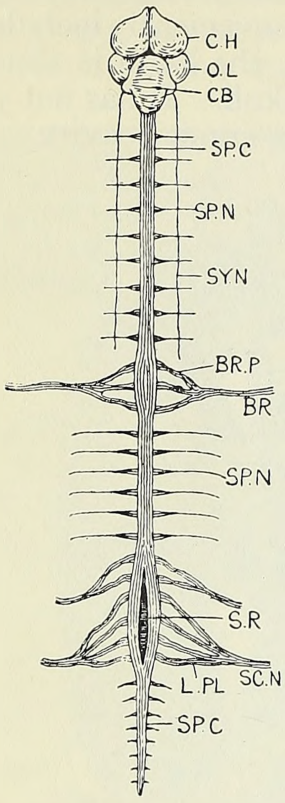


Fig. 237. Nervous System of a Pigeon

CH, cerebral hemispheres of the brain; OL, optic lobes thrust to the side; CB, cerebellum; SP.C, spinal cord; SP.N, spinal nerves; SY.N, sympathetic nervous system; BR.P, brachial plexus (to wing); S.R., rhomboidal sinus in the dilated spinal cord; L.PL, lumbar or sacral plexus of nerves uniting to form the sciatic nerve (SC.N) going down the leg.

Between the cerebellum and the cerebrum a reddish **pineal body** rises to the surface as an upgrowth from the optic thalami. Its stalk is called the epiphysis. The pineal body is not nervous in birds and it seems to correspond to what is called the parietal organ, in some other Vertebrates, which has an eye-like structure in the New Zealand lizard. On the under-side of the optic thalami is the **pituitary body**, partly nervous and partly hormone-making.

SENSE-ORGANS.—Birds have two well-developed senses—sight and hearing. The eyes are large and have great acuteness of vision, familiarly seen when a gull picks up a piece of biscuit from the white wake of a steamer, or when a hawk searches the hill-side for its quarry. The eyes are unsurpassed in their power of rapid focusing, or *accommodation*. These two excellencies must make up for the lateral position of the eyes, which can only form an image from one side at a time (*monocular vision*).

The sense of hearing comes a good second, as is evident in the quickness of the young to detect the danger-signal or some sound that they have *learned* to associate with danger. The high evolution of song suggests a similarly high evolution of hearing. There is no ear-trumpet or pinna, and the large earhole is well concealed by feathers. From the drum or tympanum of the ear a bony rodlet (the *columella*) conveys the vibrations to a window into the inner ear. The ear has also a balancing function.

The other senses are usually unimportant in birds. Only a few, e.g. magpie and owl, have a sense of smell. As they bolt their food in the majority of cases, there is not much taste. There is acute tactility towards the tip of the bill in woodcock and snipe, which feel their food in the soft soil, but there are not many instances of this; nor would we

expect much in the way of touch in creatures so fully clothed in feathers and scales.

BEHAVIOUR.—We are giving numerous separate instances of bird-behaviour, and we shall confine ourselves here to a few general remarks.

(*a*) There are many **reflex actions** (q.v.), such as the gaping, gripping, and gulping on the part of a nestling when the parent brings food.

(*b*) There are hints of **tropism** (q.v.) in the obligatory movements of migratory birds, which often keep the right direction unerringly.

(*c*) Inborn or hereditary **instinctive behaviour** for routine is well illustrated by the squatting of young birds when the parents sound the danger-signal. This instinctive behaviour is very common, but it is often mingled with some intelligence, as when the usual routine of nest-building has to be departed from.

(*d*) **Intelligent behaviour** is in some cases indubitable. That is to say, we cannot make sense of the behaviour without crediting the bird in question with some subjective activity akin to our intelligent inference.

(*e*) Many birds show great **educability**, especially in youth; and there are no better examples than chicks. They may be led to form associations and conditional reflexes, and habituations which are often very perfect, as in trained birds.

(*f*) Very characteristic, we think, of the bird-mind is the strong current of *feeling*—whether it be in the patience of brooding or in the ecstasy of courtship.

[See J. A. Thomson, *The Minds of Animals* (Newnes, 1927), Chapters XIV—XVI.]

THE BRAINS OF A HEN.—As a general rule it may be said that animals are no cleverer than they need to be. Therefore if domestication means a sheltered life, plenty of food, and little danger or adventure, we may expect expressions of intelligence to be few. Hence we speak contemptuously of ' the brains of a hen.' It is quite different with domesticated animals, like horse and dog, that become man's partners and share in responsibilities. We do not say that the hen's brains have degenerated—they seem to differ considerably in different breeds—but we say that expressions of intelligence on the hen's part are not common. It takes a long time for brains to degenerate; evolution up or evolution down is a slow racial process; but it does not take long for the brain to fall more or less asleep in a particular animal. This is an *individual* result, and we think that it is illustrated in hens. This is borne out by the **educability** of chicks. If an instinct is an inborn ready-made power of doing apparently clever things, then chicks have relatively few instincts. Almost from the first, they can peck with precision at flies moving on the wall of the hen-run; they can jump neatly from an eminence eight times their own

height; they can scratch their head with their toes; and they have a few other instinctive accomplishments. Yet how few compared with a young ant or a young bee! Chicks hatched out in an incubator paid no attention at all when their unseen and previously unheard mother clucked outside the door. They are not instinctively aware that the presence of a cat spells danger. Even when thirsty they do not instinctively recognize water, though they may be standing in a saucerful. They will stuff their crop once or twice with worms of red worsted—a very unprofitable meal! Yet how quickly they *learn*—to recognize various sounds, to discriminate between different people, to reject dangerous food such as bees, and so on. There are few animals so educable as chicks—up to their limits. We cannot believe that this educability disappears in the adult hen; we believe that it simply falls asleep except when there is some particular need or stimulus. This view is supported by some experiments made by Katz and Revesz. When they scattered mixed rice and wheat before their hens, they noticed that the grains of rice were always picked up first. So they tried a hungry hen with twenty rice grains which were glued irregularly to a slab of wood about five inches square; and between these they placed ten loose grains of wheat. At first the hen tried the rice grains, but could not detach them. It then picked up the grains of wheat. When all the ten were picked up, there was a rest for fifteen seconds, and then the hen got another lesson, and so on till it had seven. On each occasion the observers counted the number of pecks that the hen made before all the ten grains of wheat were swallowed. The figures are very interesting: 35, 19, 19, 16, 12, 10, 10. In other words, the hen had learned by the sixth lesson not to waste time over the rice grains, which were fastened, it may be noticed, with invisible glue. It had eliminated useless movements, as we ourselves do in learning to play a game or to ride a push-bicycle. We conclude that hens are not so stupid as they look, that they may wake up intelligently when the stimulus is sufficiently interesting and when brains are adequately rewarded.

Food

FOOD AND FOOD-CAPTURE.—In birds, as in all other animals, both structure and habits are in great part concerned with the quest for food. (1) Many birds are **vegetarian,** eating fruits, seeds, buds, leaves. Most humming-birds and honey-eaters suck up nectar; woodpeckers tap the sweet maple trees; geese graze on grass; grouse devour heather tips; ptarmigan often feed on the mountain lichens. (2) Many birds are **carnivorous,** eating small mammals, other birds, occasional reptiles and amphibians, many fishes, many slugs, countless forms of insects

and lower animals like earthworms. Kestrels destroy moles. the golden eagle sifts the grouse, the secretary-bird kills snakes, storks swallow frogs, the flying osprey catches the swimming fish in its talons, rooks let freshwater mussels fall from a height on the river gravel, the thrush breaks the shells of the snail on its anvil, the cuckoo is partial to hairy caterpillars, the swallow catches small insects in mid-air, the woodcock depends mainly on earthworms. The most important ecological fact is the indispensable check that birds keep on the multiplication of insects which would otherwise ruin the world. (3) Many birds enjoy both vegetarian and carnivorous diet. Thus the thrush likes fruit as well as slugs, a woodpecker may thrive on ants as well as on sap, the normally fish-eating herring-gull has become a devourer of turnips, potatoes, and grain. Of special interest among the **mixed feeders** are those which give their young ones material different from that which forms the staple food in adult life. Thus young rooks, sparrows, and finches are fed for a time on insects only. In many cases the diet has necessarily to vary with the seasons. (4) There are many strange **oddities of diet.** Thus the kea parrot (*Nestor notabilis*) of New Zealand has learned to settle down on a disabled or dead sheep and dig out the fat and flesh from near the kidneys. Fatal attacks on quite vigorous sheep have been rarely proved. This is a strange idiosyncrasy on the part of a bird that belongs to a race habitually vegetarian or frugivorous; and it must have arisen rapidly, for sheep were not taken to New Zealand till about a hundred years ago. It has been suggested that the bird began by pecking at the fat adherent to the sheepskins hung up to dry. The red-winged starlings of South Africa include in their menu the berries of the syringa, which they eat in such quantities that they become stupefied by some included narcotic. Similar intoxication has been observed in woodpeckers that enjoy the syrupy sap of the maple trees, and in some frugivorous birds that devour fermenting fruit. Another quaint maladjustment is seen in some sea birds (e.g. the albatross) which may make such a hearty meal of fish that they cannot rise off the water.

It is ecologically interesting to select a particular kind of food, let us say fish, and to notice the variety of ways in which it is obtained. The hovering osprey catches the fish in its talons, the swooping herring-gull does the same with its bill, the gannet dives from a height, the cormorant turns head over heels from the surface, the scissorbill skims the waves, the heron usually waits for a fish to swim past, the kingfisher makes a sudden plunge, the pelicans sometimes wade shorewards in a crescent, penguins pursue their booty under water, the skuas chivy the herring-gulls in the air and force them to disgorge, being quick enough to catch the falling booty before it reaches the

water. There are many other methods, all reaching the same result. As to the ways in which food is detected, acuteness of vision counts for most; a tactile bill is important to probing-birds like snipe and woodcock; of smell there is not much evidence, except in nocturnal birds of prey, to which blackbird, magpie, rook, and a few more may be added.

Another line of inquiry may be illustrated by the way in which the bills and feet of birds are suited to particular kinds of food and food-capture. The absence of teeth in modern birds is compensated for by the horny bill covering the jaws. It often has a sharp edge and a hooked tip; it varies from a massive crushing instrument in the toucan to a delicate probe in the humming-bird. The variety of type should be considered in the light of the fact that the fore-limb has been surrendered to making a wing, and that the bird's jaws have to discharge duties which in mammals usually fall to the hands. A parrot may hang with its jaws gripping a branch; a tailor-bird uses its bill to stitch leaves together with fibres.

The bones covered by the horny bill are especially the premaxillae above and the complex lower jaw below. It may be convenient to keep the word 'bill' for the horny sheath and the word 'beak' for bill and jaws together (see p. 531). The more primitive type of bill-structure is seen in birds like the albatross and the puffin (q.v.), where there are several distinct horny plates, homologous with reptiles' scales. In most birds these fuse into one sheath. In his *Evolution Theory* (1904, ii, p. 14) Weismann discusses the regeneration of both bone and horn in the bill of the stork, and correlates this with the combats of males, in the course of which serious injury is apt to occur. Similar regeneration is recorded for fighting-cocks and for a parrot. 'It should not astonish us that the bill in birds has such a high regenerative capacity, for of all parts in a bird it is the one that is most readily injured; with it the bird defends itself against its enemies and its rivals, masters its prey and tears it to pieces, pecks holes in trees (woodpecker), or climbs (parrot), or digs and burrows in the ground, or builds its nest, and so on.' According to Weismann, the regenerative capacity is likely to be conserved in those animals that are in the natural conditions of their life peculiarly liable to non-fatal injury to external parts.

A generalized bill may be illustrated by that of the crow and its allies —strong, pointed, somewhat triangular in section. Shortening, sharpening, and curving of such a bill would yield the predatory type of hawk and eagle—quick to give the death-blow by piercing the skull or cutting the jugular vein, also well suited for rapid skinning and plucking, and for drawing out strips of flesh from the body. It is interesting to see an eagle deftly run down the backbone of a

fish with its bill, dislocating the vertebrae. Somewhat of the same type are the bills of the owls and the parrots, though the former are carnivorous and the latter vegetarian. The parrot's beak has a movable hinge between the premaxillae and the front of the skull, and there are often strong file-like roughnesses to the inside of the bill, which serve in gnawing nuts or grinding hard seeds. Not very remote are the broadly conical strong bills characteristic of the finches, suited for breaking capsules and splitting seeds.

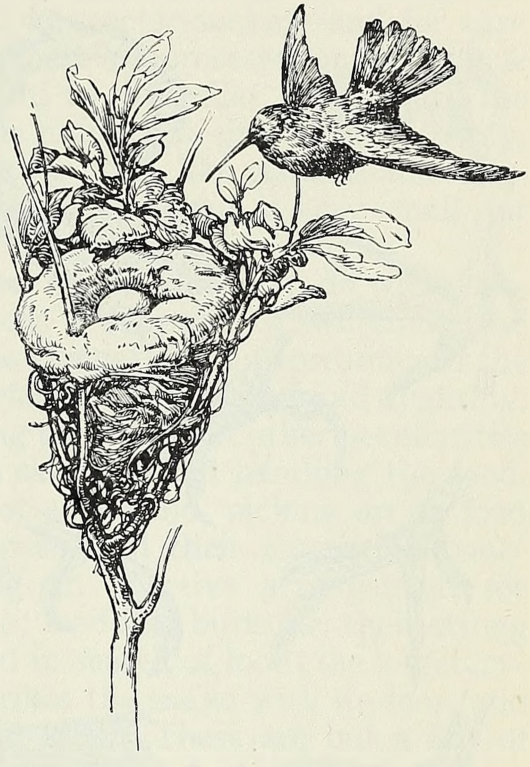


FIG. 238. HUMMING-BIRD

On another line are the delicate slender types, familiar in warblers, suited for dealing with small insects, with a climax in the elongated slender bills of hummingbirds. Not far removed, though used in a different way, are the elongated narrow bills of curlews, snipe, avocet, and woodcock, used for probing in mud, sand, and the like. In a very different direction are the broad bills of ducks and geese, well suited for sifting the mud and cropping vegetation, and on this line might be placed the broad bills of some storks and herons, and the spatulate type well seen in the spoonbill. Also broadened out, but kept very short, are the insect-catching bills of goatsucker and swift. A slight specialization of the rook type leads to the sharp spearing form of bill seen in snake-birds, herons, and bitterns. Lateral compression in puffin and razorbill reaches an extreme in the long high knife-blade of the skimmer (*Rhynchops*), a tropical relative of the terns. This bird flies very close to the surface and skims the water with the mandible, which is longer than the upper jaw. When the knife-edge of the mandible touches a small fish or crustacean it tilts the booty into the open mouth. The skimmer or scissorbill is also said to skim soft mud. There are many strange types, such as that of the crossbill, where the points of the upper and lower halves of the beak cross one another when at rest—a position that occurs as an abnormality in some birds, such as crows. The peculiarity is utilized by the crossbill in the exceedingly rapid extraction of the seeds of fir-cones, a deft manipulation in which the tongue assists. In the wrynecked plover

of New Zealand the bill is turned to the right-hand side, and it is interesting to notice that a one-sided twist is occasionally seen in an individual oyster-catcher. In the flamingo the whole beak is bent almost at right angles on itself, half-way down its length, and it has to be thrust upside down into the mud, where it searches for small molluscs and the like. The kiwi is the only bird in which the nostrils open at the tip of the bill. In the huia, another New Zealand rarity, there is sex dimorphism in the bill. According to Professor Newton, the male uses his short, strong, almost straight bill to chisel holes in decaying wood where grubs may lurk, while the female uses her much longer, decurved, and slender bill to probe into crevices. But when he, having discovered a grub in his excavations, is unable to reach it, she takes advantage of the opportunity. Darwin notes that in the short-faced tumbler pigeons the beak is so short that the unhatched bird cannot reach the shell to break its way out—an instance of a variation that would be immediately fatal unless it occurred under man's aegis.

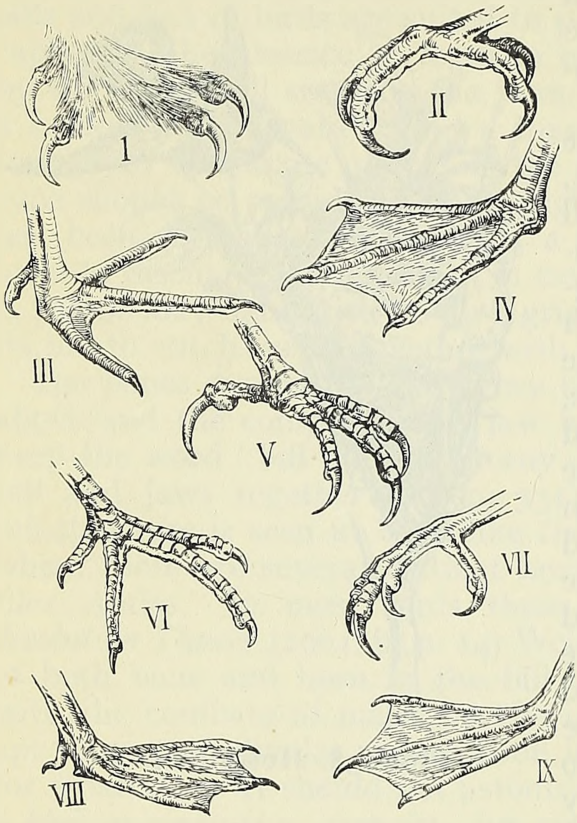


FIG. 239

VARIOUS TYPES OF FEET IN BIRDS-

I, owl; II, parrot; III, curlew; IV, gull; V, rook; VI, goatsucker; VII, kingfisher; VIII, duck; IX, razorbill.

Before leaving bills and their adaptations we may make three general notes. (*a*) The adaptations to feeding habits often show great nicety, but it should always be asked whether a bird with a peculiar bill may not have sought out a peculiar kind of food, as in the case of crossbills. (*b*) The most striking features of a specialized bill are not exhibited until the young bird begins to fend for itself. Thus the very young flamingo shows nothing of the strange deflection of the bill, and there is in the unhatched curlew very little indication of the adult's disproportionately long bill. As in many other cases, a hereditary character may have to await its appropriate liberating stimuli. (*c*) The same kind of bill may occur in birds which are not nearly related as in the case of swifts and swallows, parrots

and birds of prey. This illustrates **convergence** or *homoplastic resemblance* (q.v.)—similar structures having arisen independently in unrelated types in adaptation to similar habits or conditions of life.

The **tongue** is often adapted to assist in food-getting. Thus that of sap-sucking woodpeckers ends in a brush, while that of insect-eating woodpeckers bears spines. The tongue of the humming-bird ends in two delicate brushes, suited for nectar-sucking and for capturing small insects. In many cases there are processes on the tongue which help to guide the food backward to the gullet, or to guard the opening of the glottis, or to strain the mud, or to grip slippery booty, such as small fishes. In some fish-eating birds, like pelicans and kingfishers, which swallow their prey whole, the tongue is very small, for it is better out of the way.

Many of the peculiarities in the **feet** of birds have to do with locomotion. Thus the webbing of the toes is adaptive to swimming, the scaling and clinching to perching; the elongation and spreading of the toes may afford a profitably large surface in jumping off and alighting, or may facilitate movement on floating plants. But other peculiarities of the feet have directly to do with catching and handling the food. Thus a parrot sometimes uses its foot as a hand, picking up its food and holding it to the mouth; the owls bend their fourth toe backwards beside the first one, forming an effective arrangement for catching, crushing, and carrying mice; fowl-like birds use their strong blunt claws for scratching the ground in search of food; the secretary-bird, a kind of terrestrial vulture, strikes the snake with its foot, and sometimes kills with a single forward kick. These are but a few of the hundreds of instances of specially adapted feet and toes.

Alimentary System

PHYSIOLOGICAL.—It will be convenient now to follow the food within the bird's body. The **salivary glands,** opening into the mouth, do not seem to have great importance in birds as far as their usual function of digesting carbohydrates is concerned; for most birds bolt their food. In insect-eating woodpeckers the glue-like saliva on the tongue must be useful; in the sea-swifts (*Collocalia*) the salivary secretion is used to make the ' edible ' nest (see NESTS). Through the muscular gripping **pharynx** the food passes into the elastic **gullet,** with mucus glands lubricating it internally. In many cases the gullet is enlarged into a **crop** which serves for storage. It is not digestive except in so far as salivary juice from the mouth may follow the food; but there may be bacterial fermentation. In the hoatzin

the crop is strongly muscular and is used to squeeze the juice out of succulent leaves. In pigeons and a few parrots there is a fatty degeneration and discharge of many of the epithelial cells lining the crop. This forms the '**pigeon's milk**' which is regurgitated by both parents into the mouth of the young bird, and assists in 'gastric education.' The formation of this creamy fluid, which should not be described as a secretion, is to some extent correlated with the activity of the gonads, but it continues after the breeding season is past.

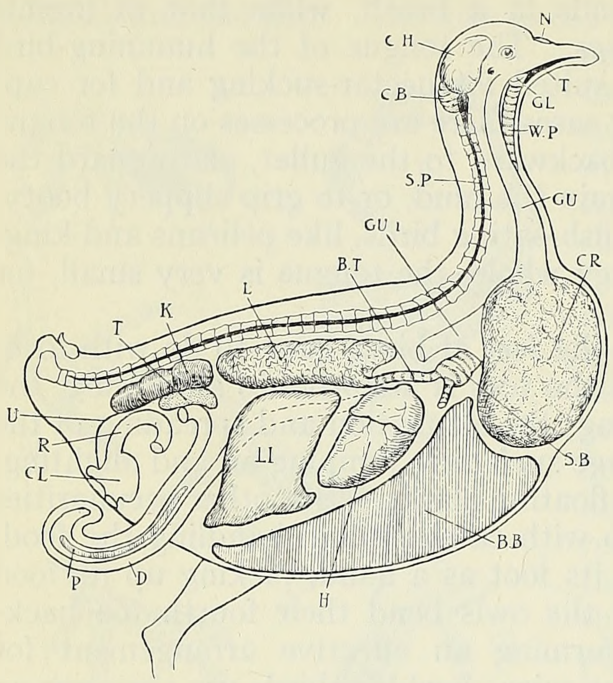


FIG. 240. POSITION OF ORGANS IN A BIRD (DIAGRAMMATIC)

N, nostril; T, tongue; GL, glottis; WP, windpipe; GU 1, gullet; CR, crop; SB, sound-box; GU, or syrinx; BB, breast-bone; H, heart; LI, liver; D, duodenum; P, pancreas; CL, cloaca; R, rectum; U, ureter; T, testis; K, kidney; L, lung; BT, bronchial tube; SP, spinal cord; CB, cerebellum; CH, cerebral hemisphere.

The **stomach** of a bird may be a simple sac, muscular and glandular, but in most cases it is divisible into an anterior glandular portion (the **proventriculus**) and a posterior muscular portion (the **gizzard**). The relative development of these two regions is correlated with the differences in diet. Thus a graminivorous bird, like a pigeon, has a strongly developed gizzard, while many birds of prey have practically none. Of much interest is the modification of the character of the stomach in the individual bird, according to change of diet. This has been observed in natural conditions in the herring-gull, which has a relatively hard stomach in summer when it often eats much grain, and a relatively soft stomach in winter when it depends mainly on fish. Analogous changes have been recorded for the raven and the owl, and have been induced experimentally in fowls and pigeons. But no hard-and-fast line can be drawn between the two types of stomach.

The bird's gizzard, which is no doubt part of the reptilian legacy, as is suggested by its presence in the crocodile, for instance, is marked by the following features: (*a*) there is on each side a strong development of muscle, numerous fibres radiating outwards from a central

tendinous disk, and bringing the two sides towards one another when they contract; (*b*) the sac is twisted on itself so that the exit into the duodenum is not far from the entrance to the proventriculus; (*c*) there is a hard internal lining or *pseudo-cuticula*, really of the nature of a secretion; and (*d*) there are numerous small pebbles which help to triturate the food. As these grindstones get their corners rubbed off, they slip down the intestine; and the bird goes out of health if they are not replaced. There are many strange gizzards, such as that of some fruit-pigeons which have numerous hard conical projections on the internal lining, or that of the snake-bird, *Anhinga*, which shows a sieve of hair-like processes at the duodenal end. These prevent unbroken fish-bones and the like from passing into the intestine. When the male hornbill (*Hydrocorax hydrocorax*) passes food to his imprisoned mate, the packet is often surrounded with a tough homogeneous skin which arises as a secretion of the walls of the gizzard.

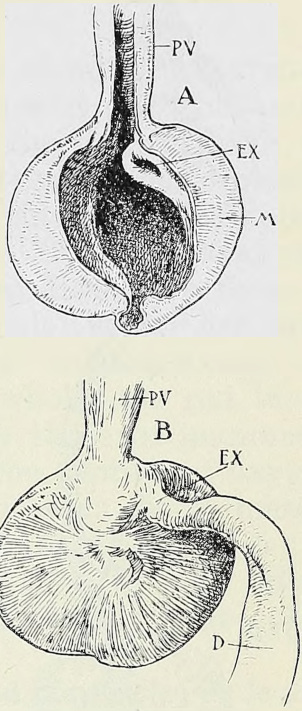


FIG. 241. GIZZARD OF TURKEY; A, IN SECTION; B, IN EXTERNAL VIEW

PV, proventriculus; EX, exit to duodenum (D); M, muscular wall of gizzard.

The most marked anatomical peculiarity of the rest of the alimentary canal in the bird is the shortness of the large intestine or **rectum**, which is often not more than an inch long. This shows that there must be great efficiency of digestion in the much looped **small intestine**. The amount of faecal matter is relatively small. At the junction of the small intestine and the rectum there are usually two **caeca**, which occur in all sizes from mere vestiges, as in the pigeon, to long functional tubes, as in the duck. When they are well developed they serve as *culs-de-sac* which delay the food on its downward passage and facilitate absorption. The terminal chamber or **cloaca** receives the ureters and genital ducts, and bears a dorsal pouch, the **bursa Fabricii**, which functions in the young bird as a seat of the formation of white blood corpuscles and lymph corpuscles.

RESPIRATION

The respiration of birds reaches a high grade of perfection. Some of the most important peculiarities are the following: the **lungs**, though relatively small and hardly distensible, have through the

complex branching of the **bronchi** a very large internal surface for gaseous interchange; the expulsion of the air from the lungs, which are fixed to the ribs, is assisted by the strokes of the wings; *expiration* is the active part of the respiratory process, not inspiration as in mammals; the lungs open into a system of transparent, internally ciliated air-sacs which economize the work of breathing and have other uses. They increase the total content of air, and this is useful in prolonged diving and in enthusiastic song; they allow of a 'double tide' in every respiratory act, thus in expiration air passes out from the lungs to the exterior, but also into the lungs from the air-sacs; they promote an internal perspiration, for water-vapour passes into them from the blood, thus helping to regulate the temperature of the body and to compensate for the absence of sweat-glands.

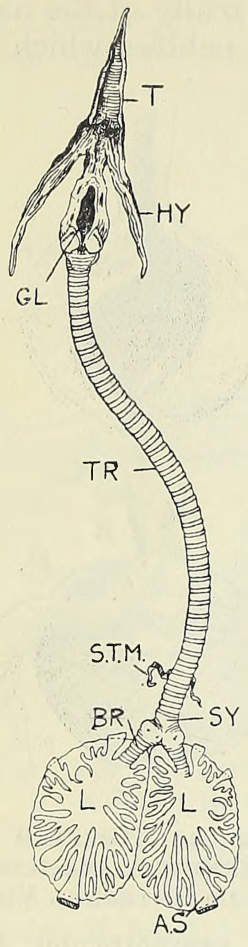


FIG. 242. WINDPIPE AND LUNGS OF A BIRD

T, tongue; HY, horns of hyoid; GL, glottis; TR, trachea; ST.M, sterno-tracheal muscles attached to breastbone; SY, syrinx; BR, bronchial tubes; L, cavity of lung; AS, meso-bronchus leading to abdominal air-sac.

At the back of the tongue lies the **glottis** or opening of the windpipe, without more than a hint of the epiglottis characteristic of mammals, a movable lid familiarly useful in keeping food from going down the wrong way. The glottis leads into the **larynx**, supported, as in Amphibians, Reptiles, and Mammals, by transformations of the representatives of the branchial arches of fishes—a good instance of a common method in organic evolution, namely the making of a new structure out of a much older one. But the larynx of birds contains no vocal cords, these being situated at the lower end of the **windpipe** or **trachea** in the enlargement known as the **syrinx** or **song-box**. This varies considerably in development and is absent in ostriches, storks, and some vultures. The voice is due to the rapid passage of outbreathed air over the vibrating vocal cords. The trachea is supported by *bony* rings, usually complete, whereas in mammals they are *gristly* [cartilaginous]. It is interesting to notice that the syrinx arises as a transformation of the base of the trachea and of the beginning of the two bronchial tubes. In contrast, again, with mammals, there is no true diaphragm in birds, shutting off the chest

from the visceral cavity. It is striking to notice how birds differ from mammals in almost every feature of their respiratory system, showing that the two classes are on very divergent lines of evolution.

Vascular System

The bird has a four-chambered **heart**, with a complete separation of arterial and venous blood, just as in mammals; but the aortic arch, carrying pure blood to the body, turns to the right in birds, to the left in mammals. The blood of birds has more **red blood corpuscles** per ounce than that of any other animals, and this is an adaptation to intensity of metabolism and to aërial habits. The red blood corpuscles are elliptical, slightly biconvex, nucleated disks, like those of lower Vertebrates, but unlike those of mammals, which are non-nucleated, slightly biconcave, and circular in outline except in *Camelidae*, where they are elliptical. On the whole, the red blood corpuscles of birds are large as compared with those of mammals. This increase of surface is probably of value in the capture of oxygen in the lungs, and it is interesting to note that whereas the diameters of the red corpuscles of man, dog, horse, and ox are 7·5 μ, 7 μ, 6·5 μ, and 5·5 μ, those of the high-flying vulture are 17·7 μ by 8 μ. By μ is meant a *micron*, i.e. one-thousandth of a millimetre (about $\frac{1}{25000}$ of an inch).

There are several different kinds of **white blood corpuscles** or **leucocytes.** Among these and of special interest are the **phagocytes**, mobile amoeboid cells, able to leave the blood altogether and to migrate into the tissues, where they engulf microbes, devour degenerating tissue, transport material from one area to another, and help to repair injuries. Thus Metchnikoff found some phagocytes that were transporting pigment granules from a blanching feather, and others (*neurophages*) which were disintegrating the brain of an over-aged parrot.

As might be expected in animals of predominant muscularity and intense metabolism, the temperature of the bird's body is high, from 2° to 14° F. higher than that of mammals. Birds share with mammals the power of keeping the temperature almost constant. That is to say, they are **warm-blooded** or **stenothermal**, a regulation of the temperature being automatically effected (see ANIMAL HEAT). The thermotaxic arrangements have not been completed in the nestlings, which are therefore apt to suffer from over-heating or over-cooling. The importance of the animal heat is that it enables the chemical reactions in the body to go on more rapidly and economically; while the thermotaxic regulation promotes smooth functioning.

Excretion

In organisms so active as birds there is necessarily a large production of nitrogenous waste-products, due partly to the wear and tear of the protein framework of the cells, and partly to the nitrogenous residue of the amino-acids into which the food-proteins are changed by digestion. The elimination of the poisonous nitrogenous waste is

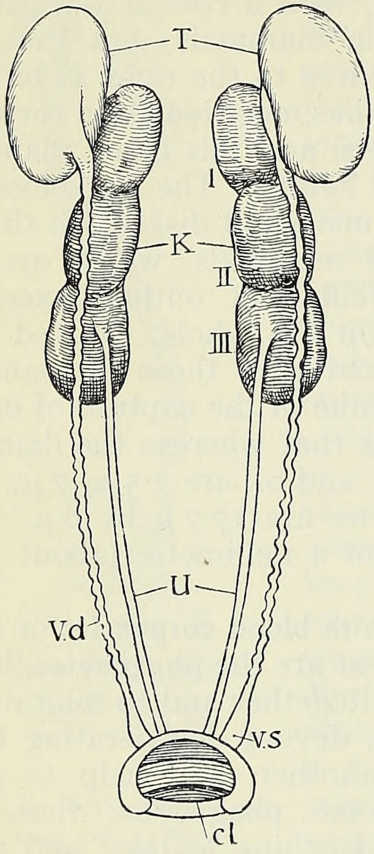


Fig. 243. Reproductive and Urinary Organs of a Cock

T, testes; K, kidneys; I, II, III, kidney lobes; U, ureters from from kidneys; Vd, vas deferens from testis; VS, seminal vesicle (a slight dilatation for the storage of spermatozoa); Cl, cloaca.

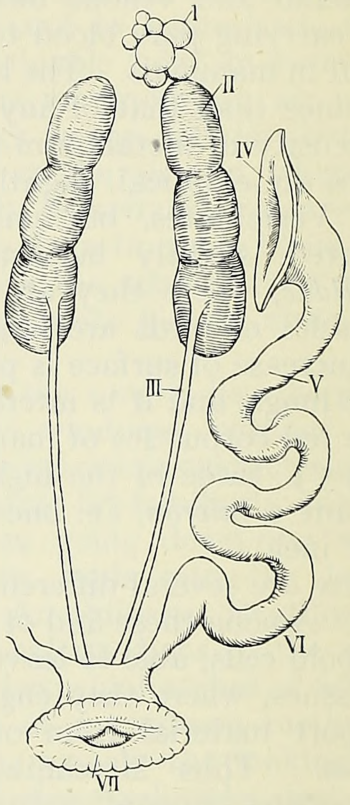


Fig. 244. Female Reproductive and Urinary Organs of a Pigeon

I, ovary; II, kidney with three lobes; III, ureter; IV, funnel at end of oviduct; VI, muscular part of oviduct; VII, cloaca.

prepared for in the **liver**, and completed in the three-lobed **kidneys** which lie below the hip-girdle. The result of the filtration is a clear fluid which passes from the kidneys by the **ureters** to the cloaca; but there, by losing water, it turns into a semi-solid mass of urates. This nitrogenous waste forms the **guano** of bird islands, such as those of Peru.

It is impossible to understand the bird's bodily life without taking account of the regulatory system of **endocrinal or ductless glands**—such as the paired *thyroids* near the base of the neck, the yellowish *suprarenals* lying on the front part of the kidneys, the *pituitary body* on the under-surface of the brain, and the glandular tissue in the reproductive organs. These structures produce *hormones* or 'chemical messengers' which are distributed through the body by the blood, and help to secure a harmonious regulation of function. Those produced by the endocrinal tissue in the gonads are important in activating or inhibiting such structures as decorative plumes and such activities as song.

Reproductive System

In Birds there is a sharp punctuation of reproductive activity, so that it is separated off from the rest of the year's life. The reproductive organs may dwindle away when the breeding season is over, so that it may be difficult to tell by a rapid dissection whether the bird is a male or a female. In many cases, as every one sees, the two sexes are very different externally—e.g. in size, plumage, and colouring. Of this **sex dimorphism** good illustrations are afforded by peacock and peahen, ruff and reeve, male and female bird of paradise; but who can distinguish a male from a female rook, or a male from a female grebe?

THE OVARY.—To begin with, the female bird has two ovaries, but for some unknown reason the one on the right disappears, and the right oviduct becomes a useless tag—a good instance of a **vestigial organ.** The ovaries arise on the wall of the body-cavity from two groups of germinal cells which have not shared in body-making. After a while the left oviduct looks like a small bunch of grapes, the ova representing the fruits.

THE EGGS.—An egg-cell in the ovary is, to begin with, a small cell; but it grows large by accumulating nutritive material from the lymph, which gets it from the blood, which absorbs it from the food-canal. This nutritive material is absorbed, transformed, and deposited as yolk by the immature egg-cell or *oöcyte*, and consists mainly of a protein called **vitellin** and a fat called **lecithin.** As a hard-boiled egg shows, the yolk is deposited in alternate zones, physically different; and it will be understood that what we call 'the yolk' is the bloated egg-cell, which carries at its upper pole a clear droplet of protoplasm, with a central nucleus. The chromosomes of the nucleus (see DEVELOPMENT) are the bearers of most, if not all, of the hereditary characters. The whole of the future embryo is built up from the droplet that lies, like an inverted watch-glass, on the top of the yolk.

Round about the dilated cell there is a vitelline membrane, the original cell-membrane; but this is soon strengthened by epithelial and connective tissue contributions which give it strength. When it becomes multicellular it should be called the vitelline *capsule*. It prevents bursting.

When the young egg has attained its full size it undergoes **maturation.** Its nucleus gives off two polar bodies, dwarf sister-cells of the ovum, and the first of these is formed by a **reducing division** or **meiotic division** in which the number of chromosomes is reduced by one-half, n becoming $\frac{n}{2}$. As a similar reduction occurs in the history of the sperm-cell, before the finished spermatozoön is formed, the normal number of chromosomes is reinstated by the subsequent fertilization, when $\frac{n}{2}+\frac{n}{2}=n$.

The ripe ovum now bursts from the ovary, and is usually caught by the trumpet-shaped or funnel-like mouth of the *oviduct*, which is usually pressed against the ovary when the bursting or **ovulation** occurs. If an egg-cell liberated from the ovary is not caught up by the oviduct, it will break up and be absorbed in the body-cavity; and in healthy birds this absorption is not unprofitable. At the top of the oviduct the egg-cell meets the ascending spermatozoa and fertilization is effected; but this seems sometimes to occur in the ovary.

TESTES AND SPERMATOZOA.—There are two well-developed testes, cream-coloured or yellowish oval bodies, situated anteriorly to the kidneys. In some cases there is inequality. The origin of these essential male organs on the wall of the body-cavity is just like the origin of the ovaries. In both sexes the adult organs show (*a*) the germ-cells, (*b*) some supporting connective tissue, (*c*) some endocrinal or hormone-making cells, and (*d*) the blood-vessels.

The ripe spermatozoa are typical, that is to say, they have (1) a ' head,' mostly consisting of the chromosomes, (2) a locomotor ' tail,' and (3) a middle-piece between the two, which bears a **centrosome** with an important rôle in the division of the fertilized egg-cell.

The ripe spermatozoa pass from the testes by delicate efferent vessels, which lead into the male duct or **vas deferens** on each side. At the base of each of these there is a dilatation (seminal vesicle) which forms a store-chamber for the sperms before they pass into the cloaca. In most cases the spermatozoa are transferred from the male to the female by the close apposition of the two cloacas during the sexual union or **treading.** This transference is called **insemination.** In ducks, geese, running birds, and a few others, the insemination is facilitated by a muscular **penis,** differing from that of mammals in

not being connected with the male ducts, for it simply arises from the wall of the male cloaca. It will be understood that the spermatozoa are very minute cells, for a hundred of them can swim about in a drop of fluid suspended from the head of a pin. Incidentally we may note that insemination has been effected artificially in hens and pheasants.

How do the spermatozoa make their way up the twisted oviduct? (*a*) They are very mobile cells, and, as is alleged for many animals, they may be able to force themselves up against a current of mucus driven downward by cilia beating in that direction (the *abovarian* cilia). (*b*) Some help may be given by the muscularity of the lower part of the oviduct, which, at a later stage, produces downward movements of the enshelled egg. That these are not invariably downward is indicated by foreign bodies, like small feathers, which may be found in the white of egg. Thus by a reversal of the usual direction the spermatozoa may be helped upwards. This kind of movement is familiar in food-canals, serving to push the food onwards, and is called **peristalsis** (q.v.). The reversal is called anti-peristalsis. (*c*) But Professor G. H. Parker has observed that in the upper part of the oviduct in the pigeon there are some lines of *pro-ovarian* cilia, which beat upwards. To their currents the last stages of the sperm's journey are probably due. The same occurs, even more markedly, in the turtle; but not, so far as is known, in the mammal. Parker found no trace of the pro-ovarian cilia in the rabbit.

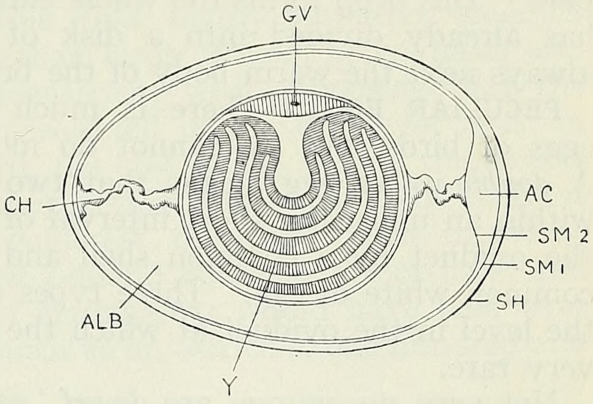


FIG. 245. DIAGRAM OF A HEN'S EGG

AC, air-chamber; ALB, albumen; CH, chalaza; GV, germinal vesicle; SH, shell; SM1, SM2, outer and inner shell membranes; Y, yolk.

THE OVIDUCT.—The oviduct is a convoluted tube with five regions. (1) The uppermost part or funnel grips the ovum liberated from the ovary, and may form a little loose albumen. (2) The second part forms dense albumen, and shows two sets of cilia. (3) The next part forms the tissue-paper-like shell-membrane and more albumen. (4) The fourth part makes the shell and more albumen, which diffuses through the shell-membrane. (5) The lowest part is very muscular and expels the egg, broader end foremost.

NEW-LAID EGG.—A newly laid egg—so readily scrutinized—shows (*a*) the porous egg-shell, through which is effected the interchange of gases necessary if an embryo is going to develop; (*b*) a delicate

double shell-membrane, which forms eventually an air-chamber at the broad end of the shell; (*c*) the white of egg or albumen, corresponding to the jelly of the frog's egg, and, strictly speaking, *outside* the real ovum; (*d*) two twisted wisps of albumen, called *chalazae*, attached to the vitelline capsule around the 'yolk,' and produced by the movement of the yolk when the brooding bird turns the egg; (*e*) the vitelline capsule; (*f*) the dilated egg-cell, which consists of the nutritive yolk and of the drop of *formative* protoplasm on its upper pole. This drop forms the whole embryo, and in the new-laid egg it has already divided into a disk of cells—the *blastoderm*. This is always next the warm body of the brooding bird.

PECULIAR EGGS.—There is much that is interesting about the eggs of birds, but we cannot do more than refer to a few points. A *double-yolked* egg means that two ova, liberated from the ovary within an unusually short interval of one another, are surrounded in the oviduct by a common shell and in the majority of cases by a common white of egg. Three types occur, which differ according to the level in the oviduct at which the union occurs. Triple yolks are very rare.

Not very uncommon are *dwarf 'eggs,'* which are not true eggs at all. The egg-shape is often departed from, and the contents consist of albumen. These false eggs arise from a blob of dense albumen which becomes surrounded with a shell.

An egg within an egg, *ovum in ovo*, seems to be due to a miniature enshelled egg, or an enshelled false egg, being forced into union with a normal egg which has not yet received its shell within the oviduct. This comes about by a reversal of the normal peristaltic contraction of the oviducal wall. Quite different from *ovum in ovo* is true twinning, when a blastoderm becomes dislocated and develops into two embryos, often abnormal.

COLOUR OF EGGS.—The shell of the egg is often very beautifully coloured; there is a predominant tint upon which are spots, streaks, and blotches of varied colour and disposition, so that the egg is in most cases characteristic of the species. But there is sometimes an extraordinary variability, as in guillemots, razorbills, lapwings, and cuckoos. These cases are interesting, because they show what abundance of material there is for Nature's sifting (*Natural Selection*) if conditions should arise in which it is all-important for the egg to have a particular colour. Eggs laid almost on the ground are often brownish like the soil; those near the seashore often look like stones; white eggs are mostly to be found in well-covered or hidden nests, like that of the kingfisher. In many cases, however, no ingenuity is able to suggest, far less to prove, that there is any utility in the colours and patterns. They express *specificity* (q.v.) or individuality, and need not have

any utilitarian interpretation. Perhaps there is none in the colouring of withered leaves, which is probably the most gorgeous display in Nature.

The egg-shell pigments are secreted by the walls of the lower part of the oviduct, and seem to be related to those of the blood and the bile, e.g. *oörhodeïn* and *biliverdin* respectively. They are probably by-products of more important processes in the metabolism (q.v.) of the oviduct. As the egg may be moved onwards before the pigments are fixed, all sorts of blotches and streaks result.

SIZES OF EGGS.—It is probable that highly nutritive sluggish birds will tend to lay larger eggs than birds of more active habit and sparser diet, but this is not inconsistent with supposing that the size in particular cases has been selected in the course of ages, in adaptation to the size of the bird, the size of the clutch, the size of the nest, the duration of the nestling period, and so on. The smallest eggs in Europe are those of the goldcrest, the largest those of swans. Some of the extinct moas of New Zealand had eggs a foot long, and those of the roc or *Aepyornis* of Madagascar would have held over two gallons—some six times as much as an ostrich's, one hundred and fifty times as much as a hen's.

DEVELOPMENT.—The individual life begins at *fertilization* (q.v.), which may be defined as the intimate and orderly union of the reduced nuclei of two sex-cells. It is a microscopic process, and not to be mixed up with the macroscopic insemination. It occurs, as we have mentioned, in the uppermost part of the oviduct before the addition of dense albumen, and it is said to take place sometimes in the ovary itself.

The segmentation of the ovum is restricted to the drop of formative protoplasm on the top of the yolk, and is of the type, seen in reptiles and most fishes, called *partial and discoidal.* The yolk serves entirely for nutrition. There are two *foetal membranes* (q.v.), which are explained elsewhere. The *allantois* by and by contains many blood-vessels from the embryo, and is spread out beneath the porous egg-shell, so that oxygen passes in and carbon dioxide passes out. If the shell is varnished the embryo must die; and another essential besides oxygen is warmth, which is in most cases produced by the brooding parent. When the embryo bird is fully formed it becomes restless (partly because of an excess of water in its body) and exhibits convulsive movements. It jerkily straightens its head, which has been bent to one side, and gets its bill into the air-chamber between the two layers of shell-membrane at the broad end of the shell. This gives the lungs their first draught of air. The so-called **egg-tooth** at the tip of the bill is used to hammer against the inside of the shell, and the young bird breaks its way out.

'COCK-EGGS.'—Every now and then the poultry keeper finds a dwarf egg from one-tenth to one-half the usual size. These small eggs have been familiar for a long time, but it was not till lately that people stopped talking nonsense about them.

According to one superstition, they are produced by old cocks, and they are called 'cock-eggs' to this day. They used to be called 'witch-eggs,' and it was believed that if they could be got to hatch they would give rise to a reptile called a basilisk, whose breath, or even look, was fatal. Sometimes they have been called 'luck-eggs,' and the superstition was that, if you threw one over the house and wished something hard while the egg was in the air, your wish would come true.

All this is nonsense, of course, and a very careful study of dwarf eggs has shown that these eggs are usually due to an accidental and temporary disturbance inside the hen at the time of egg-making. In rare cases there is something permanently wrong with the hen. About every third dwarf egg has no yolk in it at all; in the others there is yolk, but less than the usual amount. It is rare for a hen to lay a dwarf egg more than once or twice in its life. A curious thing sometimes happens. When the dwarf egg is passing down the egg-duct, before or even after it has got its shell, it may be overtaken by an ordinary egg still without its shell; the two are pressed close together and surrounded by one shell, forming a small shelled egg inside a big one.

Birds' Nests

There is a railway station in the Scottish Highlands where one can sometimes see a bird's nest inside the oil-lamp that overhangs the little platform. But that is not so strange as it seems, for the lamp is never lighted in the summer season, and it must be understood, though this is often forgotten, that what is a station lamp to us is not a station lamp to the bird. What we thought of as strange is not strange at all, except that the bird—we cannot remember what it was except that it was not a sparrow—must surely have had some feeling that it was asking a good deal of Providence. Similarly, when a bird makes a nest up the sleeve of a scarecrow, or under a railway wagon, it is not doing a very strange thing. It does not know anything about scarecrows or wagons as such; it simply recognizes a well-sheltered site and utilizes it, sometimes with very disappointing results.

A genuinely strange nest, however, is that of the sea-swift (*Collocalia*) of the Far East, which builds on seashore cliffs and the walls of caves. The dainty bird, like a small edition of our swift, makes a

nest like half a cup, and the nest is composed of the consolidated salivary juice of the mouth. Chemically regarded, the nest is made of a substance next door to mucin, and though we may wonder that the Chinese find it palatable, when they dissolve it to make 'bird's-nest soup,' we cannot wonder that it is digestible. For mucin is a protein substance commonly secreted by salivary glands and delicate skins like those of fishes. Anyhow, this substance makes the nest of the sea-swift. When it is pure it looks a little like the frosted sugar on a cake, but it is often discoloured with seaweed, and not what is called 'white' or 'first quality.'

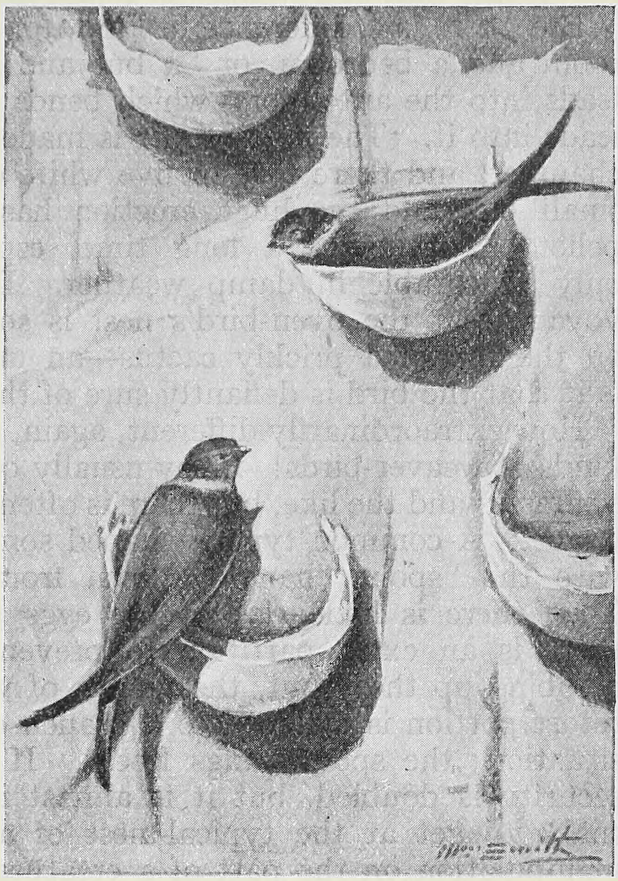


FIG. 246. SEA-SWIFT (*Collocalia*) AND EDIBLE NESTS

Huge numbers of sea-swifts sometimes breed in a great cave, sticking their nests close together on the cliff, so that they are practically touching. Using boats and ladders and long-pronged forks, the natives collect large numbers of the nests and send them off to China, where they are said to be worth their weight in silver—but they do not weigh much! When the nest is stolen, the bird builds another, but not so good. It may come down to making a seaweed nest. It should be noted that there are over a dozen different kinds of sea-swift, and the nests differ a little in detail. They are all, however, essentially saliva-nests, and therefore, we think, the strangest nests in the world. We cannot leave them without noticing that the sea-caverns where the sea-swifts nest are sometimes the abode of legions of bats, which do not make the place more fragrant. There is an interesting 'Box and Cox' arrangement, for the bats occupy the cave by day and hunt at night, whereas it is the other way round with the sea-swifts, though they are there all the time when brooding. The sea-swifts are not migratory birds.

As massive as the sea-swift's is delicate is the nest of the South

American oven-bird or baker-bird (*Furnarius*). It is about the size of a child's head and heavier, and it is built on a very conspicuous place, such as the top of a post, a leafless branch, or a bare cliff. Its walls are made of clay and dung, strengthened with some hair or grass, and they become almost as hard as brick. The oven-bird's nest is like that of a swallow or house-martin raised to the tenth power.

But there is a difference in kind, for it has two chambers, an ante-room and a bedroom, or 'a but and a ben.' An upright doorway leads into the ante-room, which bends partly round the bedroom and leads into it. The nest proper is made of grass and hair in the inner chamber, and there four or five white eggs are laid. The bird has a small bill, and the huge erection has to be constructed pellet by pellet. This takes a long time, especially as the materials are only procurable in damp weather. Darwin noticed on his *Beagle* voyage that the oven-bird's nest is sometimes perched prominently on the top of a prickly cactus—an uninviting shrub to climb. Or is it that the bird is defiantly sure of the safety of its fortified cradle?

How extraordinarily different, again, are the nests woven by various kinds of weaver-birds! They usually consist of the interwoven stems of grasses and the like, but there is often softer material in the essential cradle. A common type is shaped somewhat like a chemist's retort, with the 'spout' hanging down from middle or top of one side. Thus there is little risk of the eggs tumbling out, and sometimes there is an extra partition to prevent this. The bird gets in by climbing up the spout, the mouth of which opens downwards. The retort portion is fastened to a branch or to reeds, or in some similar situation; the spout hangs freely. If the nest overhangs water its security is doubled, but it is almost impossible for a monkey or a snake to get at the typical nest of a weaver-bird. As a piece of manipulation on the part of a creature without hands, the nest is a triumph. There are all sorts of *finishing touches*, as when the Indian 'baya' counterpoises the cradle portion with lumps of clay so that the nest does not tilt!

Matchless is the nest of the eider-duck, built on the ground, a large quilt of feathers—but feathers plucked from the bird's own breast—surrounded by a foundation of grasses, twigs, and, perhaps, seaweeds. When crafty man, taking advantage of the eider-duck's trustful disposition, induces her to brood under his care, the result may be a very fine nest composed almost exclusively of the grey down-feathers. This beautiful quilt is appropriated by man, and this forces the urgently maternal bird to begin again. And her second nest is on a much lower level than the first, for she has not much more down to spare. We wish it were true, but it isn't, that she then seeks out the drake and plucks him! He is safely out at sea.

We have tried stroking an eider-duck on the nest, knowing that she sits 'very close.' The result was an explosion, for which we admit we were not unprepared. We retreated just in time to avoid receiving part of a sudden spray of disagreeable oily stuff voided by the anxious mother as she whirred off to the sea. When she leaves her nest in a normal way to snatch a meal offshore, she draws the sides of the downy quilt over the eggs, so that they are not chilled and addled during her short absence. When the ducklings are out, the drake *sometimes* condescends to come back, and then he seems quite proud. As, indeed, well he may be.

In many parts of Africa and in Madagascar there is a curious bird called the hammerhead or umber. It is related to herons and feeds mainly on aquatic animals. The back of the head bears a strong tuft of feathers, carried horizontally when the bird is not excited, and giving rise to the name hammerhead. About the size of a raven, the bird has an earthy-brown or umber colour; but the strangest thing about it is its nest, which may be six feet in diameter! It is built on a tree or a rocky ledge, a compacted dome of sticks, roots, grass, and rushes. The interior is neatly plastered with clay. Some travellers say that the whole erection is strong enough to bear a man's weight. The doorway is always relatively small and not easily seen. It leads into a porch, where one of the birds keeps watch during the brooding time. The second room is a parlour, where bones of frogs and fishes are often to be seen lying about in untidy confusion. Farthest in is the bedroom, where the nest proper is to be found, three to five white eggs being laid on a soft cushion. The parents alternate between brooding and keeping watch. According to the natives, the hammerhead is an uncanny bird; it certainly makes one of the strangest of nests.

A nest is essentially a cradle and therefore a private affair. Yet the social note is occasionally struck. In some cases, as with our sand-martins, the explanation is that suitable sites are not common. Therefore when one is found, it must be shared. There is a South American parrot, called 'the monk,' a notorious robber of orchards, that makes an intertwined nest of the thorny twigs of the tala tree. There are two chambers, an inner for the eggs, an outer serving as a porch; and on one side there is a door with overhanging eaves. The nest is built on a branch, and the same tree is often used by many birds; so many, indeed, that the aggregate may be big enough to fill a cart. There are some other peculiarities. Thus the nests are used as shelters all the year round, and the porch is sometimes occupied by another bird or by an opossum!

Even more striking is the co-operative nesting of the South African sociable weaver-bird, where many individuals combine their energies

to build an umbrella-shaped thatch of sticks and straw among the branches of an acacia tree. From the under-side of this roof each pair of birds hangs its pendulous nest, and there may be twenty to forty altogether. They are well protected by the thatch both from rain and from enemies, but sometimes the acacia breaks down, and love's labour is lost.

A FEATHER-POKE NEST.—In the spring of 1932 we had an enjoyable opportunity of studying the nest of a **long-tailed tit.** It was fastened to the slender branches of a spruce tree and mostly camouflaged with grey lichen. The rest of the *outside* of the nest was composed of green moss intertwined with a little wool and some delicate fibres. The ' door,' which is usually near the top on one side, seemed to be closed, and before the nest was deserted it may have been closed by the long tail, which is about three inches in length to a body of two inches. The nest was about five and a half inches long, so that there was not much free play for the builder, especially since the interior was almost filled with hundreds of small feathers, neatly woven into a quilt, admirably suited for the vagaries of British spring weather. We have heard that its only imperfection is the lack of any arrangements for draining off too frequent showers. The nest may become water-logged and the crowded young ones may drown or die of cold. As is the way with wrens, the long-tailed tits sometimes use the ' feather-poke ' nest as a winter shelter, and it is certainly inviting. As many as 2,379 feathers have been counted in the nest of the long-tailed tit; and these have to be gathered and ' handled ' individually by the parents, who require about a fortnight for their delicate work. As the nest has **survival value** in securing the welfare of the young, and as the maker of the quilt is a very successful bird, extending from Britain to Japan, and very hardy, joyous, and adventurous every-where, in spite of its seeming frailty, we see the inaccuracy of the idea that Darwin's **struggle for existence** always involves internecine competition. The quilt of the titmouse—a skilled response to cold weather as well as to the hungry eyes of enemies—pays in Nature's sifting as surely as does the equipment of the hawk with beak and talons. The struggle for existence is often an artistic endeavour after well-being.

We do not know which to admire most, the inside or the outside of the 'feather-poke,' both made of material which has to be collected from elsewhere. But on the whole the piecing together of the outside lichen seems to us the most remarkable feature of this ' home without hands.' Miss E. L. Turner speaks of the fine picture seen when the bird clings to the outside of the cradle or nursery. ' The soft blending of black and white in its plumage, together with the flush of pink on breast and flanks, make a beautiful colour scheme which somehow

melts into the silver-and-black lichen composing the exterior of the nest. The tail is then used as a support, being curved elegantly upwards, giving an idea of hitherto unsuspected strength latent in this long slender appendage.'

The bird seems to be instinctively or innately endowed so that it must make this type of nest, but it is difficult to refuse to credit it with some measure of selective appreciation. There is a spice of individuality in the achievement, and the bird looks as if it enjoyed its artifice. In the strict sense, we suppose, art is the deliberate expression of an idea or an emotion in some significant medium, and 'instinctive art' is almost a contradiction in terms. Yet we must not be too sternly logical with life, or ignore the element of purposiveness behind the bird's behaviour. The nest-making is long-drawn-out, but the bird does not wander from the point; it is patient and yet joyous; it is to some unknown extent suffused by an awareness that what is being fashioned is a cradle. Thus perhaps it draws near the confines of art. And the result excites our sense of beauty, our sense of wonder, and 'thoughts of things that thoughts do but tenderly touch.' It is the kind of thing that the biologist cannot leave out of his philosophy.

And if you are so hard of heart that you regard all such talk as irrelevance, then, we suppose, we must remind you that the very industrious fashioners of the feather-poke nests feed their young ones from dawn to dusk with caterpillars small and large, whose reduced numbers mean increased prosperity to the farmer.

The Brooding Bird

In early summer all over the country, in tens of thousands of nests and apologies for nests, there is the yearly wonder of the brooding bird, still very imperfectly understood. Squat on the ground or swaying on the tops of trees, hidden in the hedgerow or deep in a sand-pit burrow, perched on a mid-stream boulder or ensconced in the cranny of a wall, there are countless nests with eggs on which the birds are sitting, often anxious-eyed. What is the true inwardness of this patient incubation, of which the birds themselves seem often to have little understanding? For many a pigeon will continue sitting on nothing, while her two eggs lie exposed and retrievable three or four inches away. Brooding is instinctive, as we say, and the inborn prompting is so strong that many a bird has been known to sit on a nest built on a caravan or the like, which by and by begins to move about.

To understand brooding we must go far back, when sundry back-boned animals forsook the water for good and found a permanent

home on dry land. These were pioneer reptiles, for few of the amphibians which anticipated them are able to dispense with the water as a cradle for their eggs and offspring. One foot on land and one in water most amphibians remain; but reptiles became entirely at home on the solid earth. That some of them long afterwards returned to the water, like turtles and sea-snakes, is another story.

While the conquest of the dry land brought with it many rewards, one of its difficulties was the safe disposal of the eggs and the young ones, which could not well be left exposed on the ground. Some reptiles solved this difficulty by burying the eggs, and a few by bringing forth young ones so well advanced that they were more or less able to look after themselves. The second solution was brought to perfection in many of the viviparous mammals; the first solution was elaborated in the nesting birds. Some snakes protect their eggs by coiling round them, and this was the beginning of brooding.

The need for the brooding of birds is threefold. Firstly, the development of the egg, with its thousands of cell divisions, is slowed down when the temperature falls below a certain point, often about 28° C., and if the cooling continues it is fatal. No doubt ostriches leave their eggs exposed during the day in hollows in the well-sunned desert sand, but the cock broods at night. No doubt the mound-birds place their eggs in heaps of fermenting vegetation and the like, but this is also an exception that emphasizes the need for warmth if development is to continue.

A second use is involved in the fact that when the young bird is hatched out, it is imperfectly warm-blooded. The regulating nervous arrangements that adjust the production of heat to the loss of heat have not been finished, and the young bird approaches the ancestral reptile in its cold-bloodedness. On a cold day it soon dies if the nest is deserted. The warmth of the parent's body is life-saving. Thirdly, there are various ways in which the presence of the brooding bird may protect the eggs and the nestlings. They are hidden from hungry eyes; they are sheltered from rain and snow; they are screened from the glare of the sun. In many cases, of course, this is effected by the nature and the position of the nest.

Many brooding birds show bare patches with a more or less mechanical origin, but probably useful in bringing the warm skin into direct contact with the eggs. More striking is the ' brooding organ ' of a few birds like the crested grebe, which is prepared for in the immature bird. It involves a disappearance of the fatty layer underneath the skin and the development of a network of blood-vessels. Another physiological change in ground birds like partridges is the suppression of scent at the nesting time. How this is effected we do not know; only theoretical suggestions have been made. But there seems to

be no doubt as to the fact that a first-rate dog may be taken to within a foot of a sitting partridge without his showing any interest, always provided that he does not happen to see the bird. In some cases, as in pigeons, the female bird is somewhat exhausted after egg-laying, and this may increase her willingness to rest quietly.

In many kinds of birds the whole duty of incubation is discharged by the female, but in many others, especially among the perching birds, the male does his share. Albatross and eagle-owl may be mentioned as birds among which the female does all the brooding; in the notable case of the hornbill the female is imprisoned in a hole in a tree, and the male has to feed her and the nestlings for weeks. In the case of the emu and the South American ostrich or *Rhea*, the cock bird does all the brooding; and so it is with the grey phalarope and a few other queer birds where the female does the courting. There is some discrepancy in the accounts given of the true ostrich, but it seems that the male does most of the incubation, which is largely restricted to the night, but that one of his attendant females may insist on brooding a little during the day. Pigeons are familiar instances of regular alternation between cock and hen.

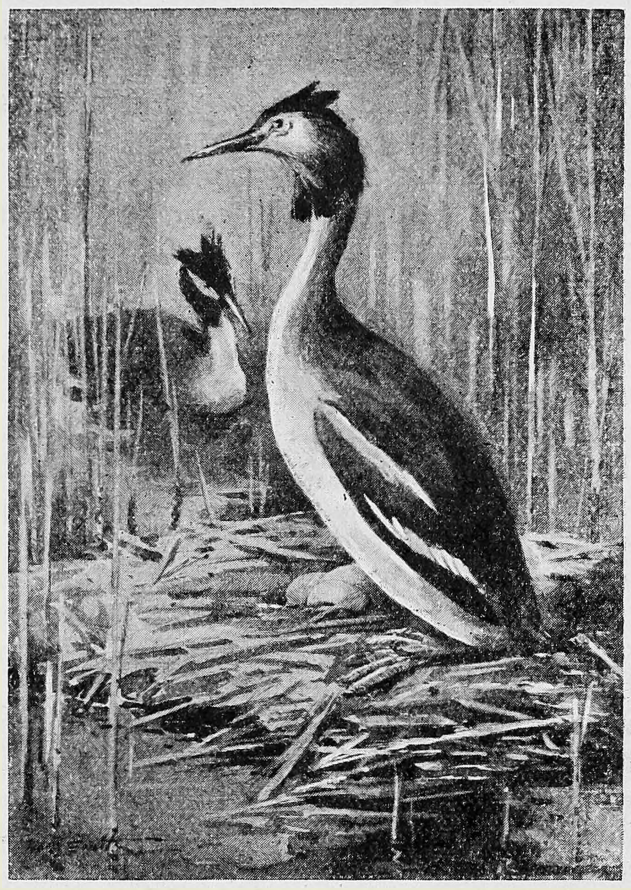


FIG. 247. CRESTED GREBES

Without being too inquisitive, we have been watching the brooding of a song-thrush in the garden, and it seems to us to be a very tedious business. The bird has taken a fortnight to hatch the eggs, and that is a very common period of incubation among the smaller British birds. A raven is said to incubate for eighteen days, a pheasant for over three weeks, a swan for thirty-five to forty days, and a solan goose for at least thirty-nine, which demands a long patience. It must be a relief to be an eider-duck, which draws the quilt of feathers over the eggs when she goes off for food.

In trying to understand brooding on its psychological side, we must avoid two extremes. On the one hand, the bird's behaviour is an expression of its hereditary equipment, its instinctive routine. In-born nervous prearrangements operate when appropriate external and internal stimuli pull the trigger; the incubation is a link in a chain of instinctive activities, such as building the nest and laying the eggs there. The strength and the automatism of the instinctive promptings may vary considerably in the same bird, and they are very diverse in different birds. Under natural conditions there is little risk of anything going wrong with the routine; the more automatic it becomes, the more profitable it will be. Therefore we must not misunderstand the apparent stupidity or futility of some birds which continue brooding long after the case is (from the ornithologist's point of view) quite hopeless, or which sit on nothing—with their eggs lying a few inches from the nest.

On the other hand, we must avoid the extreme of refusing to credit any bird with appreciative awareness of what it is about. The pathetic appeals of the disturbed parents suggest a high tide of feeling. Their tricks to distract attention from the brood are no doubt in part instinctive, but they sometimes show plasticity. Even when there seems to be no recognition of the egg as such, a new note of affectionate ownership is sounded when the young birds appear. Moreover, it seems absurd to deny birds any memory of what happened the year before. But it is especially important to keep in mind that birds may have acted intelligently and controlledly in ancient days when new departures or variations in hereditary reactions were being tested and sifted, in the slow process of building up one of the most wonderful instincts in the world. Though instinct is not lapsed intelligence, appreciative awareness may have been a factor in its evolution.

BROODING BY PROXY.—Many species of the cuckoo genus (*Cuculus*), and of related genera, have the so-called ' parasitic ' habit of foisting their eggs on other birds. The familiar *cuckoo*, whose notes form such a distinctive part of the May music of Britain, has certainly made a success of the strange custom of shirking parental duties and securing *brooding by proxy*. How does the mother-cuckoo effect her purpose? Mr. Edgar Chance has given a fine cinematograph demonstration that in certain cases the mother-cuckoo *lays* her egg in the chosen nest, and that she may previously make room by carrying off and destroying the egg that has a right to be there. That the laying which may occur in the meadow-pipit's nest is not the method always adopted, is plain from the occasional occurrence of the cuckoo's egg in such nests as those of the wren, the tree-creeper, and the reed-warbler, where it would not be possible for the cuckoo to sit.

The cuckoo's egg, incubated by the foster-parent, develops rapidly, and the newly hatched bird, which is usually big for the nest, proceeds to eject the rightful tenants, if there are any left. It must not be supposed that the young cuckoo does this with the intention of securing the whole of its foster-parents' attention; it has an exaggerated 'touchiness,' especially on the small of its back, which makes it move convulsively if it is touched by one of its companion nestlings. The result, however, is all in favour of the young intruder. The foster-parents, without appearing to notice the fate of their own brood, devote themselves to rearing the cuckoo, and sometimes work themselves almost to exhaustion-point in order to satisfy its big appetite.

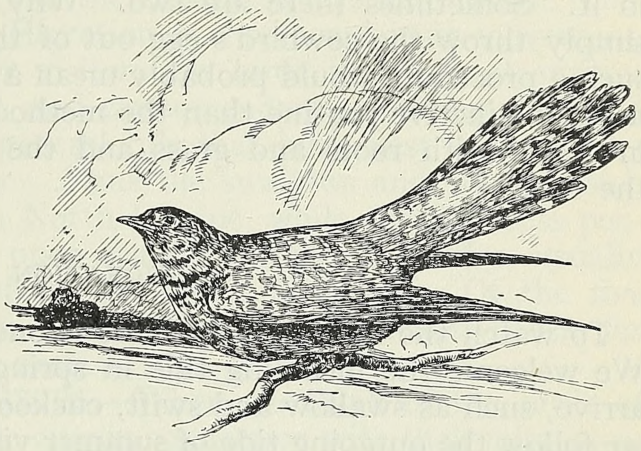


FIG. 248. CUCKOO

As to the larger problem, the meaning of the cuckoo's trick, it must be borne in mind that birds follow a routine of behaviour, partly instinctive and partly intelligent. They arrive in spring, they choose a territory, they court and pair, they make a nest, they brood, they nurture and educate their young, and they say good-bye. Now, slight variations in this routine are not infrequent. Thus a bird may make two nests; a bird may use the nest of a neighbour; a bird may have two broods when one is normal for the species; a bird may brood on dead eggs; a bird may forsake the nest without sufficient cause. Variations in the timing of events are not uncommon among animals. One chapter of the life-history may be telescoped down and another lengthened out; one train of activities may be exaggerated and another become rather perfunctory. In the most general terms, as has been suggested by Professor Herrick, the cuckoo illustrates a **temporal variation**—the telescoping of the incubation chapter. That the method pursued sometimes differs in detail is a hint that the variation is not yet very ancient. That the new departure has paid is obvious.

COWBIRD OUTWITTED.—The North American cowbird (*Molothrus ater*) used to be the everyday companion of the bison, and when the great herds dwindled away it transferred its attention to the introduced cattle. As with starlings in Britain, it picks up the insects which the cattle raise from the ground and also those which are always attracted by a herd. Like the European cuckoo, the cowbird builds no nest, but utilizes that of some other bird. When the

young cowbird is hatched out it does not oust the rightful tenants of the nest as our cuckoo often does, it simply insists on getting all the food that the ' duped ' foster-parents bring. Thus the other nestlings die of starvation. Dr. Charles Macnamara records the interesting fact that the yellow warbler (*Dendroica aestiva*) often detects the intruded egg and refuses to accept it. Nests are found that are four or five inches high, instead of the usual three, and the additional height is due to an unusual thickness in the floor. If you probe into this heavy base, you are almost sure to find a cowbird's egg embedded in it. Sometimes there are two. Why the yellow warblers do not simply throw the cowbird's egg out of the nest it is hard to say, but such a procedure would probably mean a greater departure from their usual instinctive routine than the method they pursue of burying the intrusion with roots and grass and the other building materials of the nest.

Migration

To watch the migration of birds is one of the delights of the year. We welcome the incoming tide in spring, when the summer visitors arrive, such as swallow and swift, cuckoo and nightingale; in autumn we follow the outgoing tide of summer visitors returning to the south, and wait for the appearance of the winter visitors. Bird-migration is a yearly ebb and flow between the winter quarters—a feeding- and resting-place—and the summer quarters—a breeding- and nesting-place. It is an old-established custom, wrapped up with the evolution of climate, the march of the seasons, and also with the intricate business of handing on the torch of life to another generation.

We must not think of migration as confined to birds, for it is well illustrated by salmon among fishes, by Open-Sea turtles among reptiles, by reindeer among mammals, and even by the land-crabs that go down to the sea to spawn. But it is at its best among birds. It is not to be mixed up with the trekking that is sometimes seen when huge numbers of locusts, for instance, leave their depleted home country under the spur of hunger, and hurry wildly forth in search of food. In the case of the Scandinavian lemming, a rodent suggestive of a small edition of a guinea-pig, there is a hunger-march from the table-lands every four years or so, and the shores of the Baltic and the North Sea may be strewn with their drowned bodies; but as there is no return journey we should not call this migration. Nor is it a genuine migration when herring or mackerel follow their delicate booty of small crustaceans from one part of the sea to another. When we have a good word like migration, is it not a pity to blunt it?

MIGRANTS AND RESIDENTS.—We get an interesting light on bird-

migration when we contrast a tropical country, where the seasons are but slightly marked, with a north temperate country, where the distinctness of the seasons makes the year, as Stevenson said, ' a cheerful and a changing page.' Mr. Beebe, Travelling Naturalist to the New York Zoological Society, once took a census of the birds in a square mile of tropical forest in British Guiana, and found that there were rather over four hundred different kinds. Now this is about the total number on the British list. But whereas far over three hundred of our birds are distinctly migratory, this cannot be said of more than about forty in the Guiana square mile, where there are practically no seasons. Migration is a seasonal mass-movement. In other words, our summer visitors are birds that cannot survive breeding in a warm country, and cannot endure wintering in a cold one. This brings us to the general rule that birds nest in the colder part of their migration range. Thus the swallows and storks which winter in Africa may nest in North Europe, while the flightless penguins, which winter on the open sea in southern latitudes, usually brood on the cold shores of the Antarctic continent. Of the five kinds of grey goose found in Britain in winter, four nest in the far north, and only the grey-lag nests in this country.

SUMMER AND WINTER VISITORS.—When we think of the birds of a north temperate country like ours in connection with their migration, we recognize five groups. First, there are the always welcome **summer visitors,** such as swallow and swift, wheatear and warblers, cuckoo and nightingale, who arrive from the south in spring, nest within our bounds, and return in late summer or in autumn to their southern and south-eastern winter quarters. Second, there are the **winter visitors,** such as the fieldfare and the redwing, both first cousins of the song-thrush, the snow-bunting, and the great northern diver, and many ducks and geese, who stay with us in winter but fly north in spring to their frigid nesting-places. There is no difficulty in the fact that a few of our winter visitors occasionally nest within our bounds; thus some snow-buntings or ' snow-flakes,' as they are prettily called, nest every year on one or other of the mountains in the north of Scotland. Third, there are the **birds of passage** in the strict sense, like some of the sandpipers, the great snipe, and the little stint, which usually rest for a short time only in a country like Britain, on their way further south or further north, as the case may be. Fourth, there are what are called **partial migrants,** a group larger than used to be supposed. We mean by ' partial migrants ' those birds which are never without their representatives in the country under consideration, yet some always migrate while others remain resident. Those that migrate may have their places taken by immigrants from elsewhere. To take an example, there is not a month in the year

when lapwings are not to be observed in Aberdeenshire, yet by marking large numbers of them with light aluminium rings stamped with an address, it has been possible to prove beyond all doubt that there is a regular autumnal migration of lapwings from sterner Scotland to more genial Ireland. Similarly, there are always goldfinches to be seen in the south of England, yet many leave our coasts in October, and there is a corresponding return in April. Fifth, there are the strictly **resident birds**, such as, in Britain, the red grouse and the house-sparrow, to take a sacred and a profane example. We do not mean that even the red grouse remains in the same place year in and year out; but, apart from artificial introductions, it is not known outside of Britain. Many of our so-called resident birds turn out to be partial migrants, as is true of rooks, skylarks, and song-thrushes. Some go and some stay.

One should avoid thinking in any formal way of these five groups —summer visitors, winter visitors, birds of passage, partial migrants, and residents—for a species that is resident in one part of the country may be migratory in another; and it is plain that the summer visitors of a northern country will be the winter visitors of a southern. Perhaps we should make a sixth group for rare stragglers or **casual vagrants**, such as the killdeer plover from North America, or Pallas's sand-grouse from the Asiatic steppes, or the waxwing from the Scandinavian pine forests.

VELOCITY OF MIGRATORY FLIGHT.—The facts of bird-migration are wonderful enough, so it is a pity that exaggerations have become current (cf. pp. 553, 555). Thus it has been alleged that some migrants attain a velocity of 250 miles per hour, which is quite incredible as a sustained effort. Rates of over a mile a minute seem to be extremely rare. Migrating crows attain to 30–45, falcons to 40–48, geese to 42–55, ducks to 44–59 miles per hour. There is no support for the old view that birds can keep up in migration the accelerated velocity which they may show for a short time when in pursuit of prey.

As to the length of uninterrupted flight, there is no possibility of resting (except on the sea or on a ship) on or near the direct route followed by the Pacific golden plover in returning from its nesting-place in Alaska to its winter quarters in Hawaii, some 2,000 miles; but so long a flight without a break is quite exceptional. Storks are strong birds, but they often take rest on the lands over which they travel in their autumnal flight from North Europe to South Africa. Two hundred miles is probably a good day's work for a migrating bird, and its day does not usually exceed eight hours. The record for actual extent of migration range is to the credit of the Arctic tern, which may spend our winter in the summer of the Antarctic Circle.

ALTITUDE OF FLIGHT.—Some birds, such as hooded crows, skylarks, and starlings, may be seen migrating in flocks at low levels, like clouds of smoke over the waves, yet the idea has become widespread that most migrants travel at great altitudes, such as 10,000 or 20,000 feet above the ground. But the evidence of several airmen, who have also been expert ornithologists, is entirely against this exaggeration (cf. p. 556). Very few migrants are seen above 5,000 feet and not many above 3,300 feet; most fly below 3,000 feet, perhaps below 1,500 feet. These figures refer to the height above the earth's surface at particular places, for it is well known that many migrants cross the passes of the Alps or the Himalayas at heights of over 10,000 feet above sea-level.

SPRING AND AUTUMN FLIGHTS.—Another general fact is the contrast often marked between the northerly spring flight to the nesting-places and the southerly autumnal flight to the winter quarters. The spring flight is often more impetuous and continuous and direct than that in autumn. In many species the males arrive first in spring, and may select a nesting 'territory,' as it is called, before their future mates appear on the scene, as is well known for the warblers. The autumn movements are often on a grander scale, for the ranks have been recruited by the young birds of the season. There are often preliminary congregations and false starts; and the flight is more dallying than in spring. The young birds either go off first or accompany their parents; the adult cuckoos are notoriously exceptional in leaving a month or more ahead of the young ones, whom they have never known.

NOTHING HARD-AND-FAST.—We must emphasize the importance of not thinking of bird-migration in any hard-and-fast way. We have spoken of spring and autumn tides, but, as a matter of fact, migratory movements are spread over the greater part of the year. We have spoken of northerly and southerly flights, but in many cases the direction is diagonal, and many European birds move from east to west in autumn. There are no doubt favourite routes, such as along coast-lines, chains of islands, and river valleys, but the advances and retreats are often over broad belts of country. There is no doubt as to the great distances sometimes covered, e.g. from North Europe to Natal, but the migration may be, and often is, a very unsensational flitting from one country to another.

THE RIDDLE OF MIGRATION.—In Professor Rowan's *Riddle of Migration* (1931), stress is laid on the duration of daylight, a factor long since recognized by Sir E. Sharpey-Schafer of Edinburgh. Dr. Rowan has particularly studied the crows and juncos in Alberta, his inquiry being mainly concerned with the immediate stimuli which activate the hereditary predispositions to migrate, and the inborn

qualities which make migration more or less successful. Granted the hereditary endowments, established no doubt by prolonged natural selection, what are the immediate stimuli in the autumnal flight to winter quarters? One thinks of the increasing cold, the scarcity of food, perhaps the reduction of ultra-violet rays, and so on, but Dr. Rowan regards the varying length of the day as the most important external factor, and it may be noted that at Edmonton, where he worked, the duration of daylight was nineteen hours on 21st June and less than nine hours on 21st December.

To theorize is easy, but Rowan has experimented. In early winter he put numbers of juncos (related to our buntings) in cages with electric light, and increased the illumination by five minutes each evening, until in January they were being illuminated up to 11 p.m. This seemed to suit the birds very well, though they normally migrate to southern winter quarters, as far off as Mexico. The male reproductive organs, which normally dwindle very markedly after the breeding season, attained their maximum summer size, and the birds sang, even in unheated cages. It may be noted here that ' control ' birds in cages with ordinary daylight remained in the non-breeding condition. On the other hand, those kept in non-illuminated cages with artificial moving bars, which insisted on great activity on the birds' part and kept them long awake, showed full vigour in their reproductive organs.

When the juncos were released they showed no inclination to leave the experimental station. This was true both for those with gonads at maximum size and for those with the organs entirely quiescent. This confirms the view that birds usually migrate when their reproductive organs are in a transitional stage, either waning (after breeding) or waxing (before breeding), when the **endocrinal or interstitial tissue** of the gonads is most abundant or active. When ' experimental ' birds in this transition stage, either waning or waxing, were liberated in midwinter, 40 to 80 per cent of them disappeared. Somewhat similar experiments were made with crows.

If the investigation is continued, the number of birds utilized should be greatly increased, but a preliminary case has been made for Rowan's theory that the internal trigger-pulling stimulus of the migratory activity is to be found in the reproductive organs, and particularly in their endocrinal or hormone-making tissue, and that this is directly influenced by the seasonal changes in the duration of daylight. It is evident that the liberating stimuli which operate in a tropical area, where the seasons are but slightly punctuated, may be different from those which operate in birds like the juncos, which are summer visitors to the far north; but Rowan does not pretend that his interesting theory has universal application.

Carrier Pigeons

Who can fail to be interested in the carrier pigeon, famous for centuries for its sureness in finding its way home? How romantic would be the story, if any one could tell it, of the situations that the carrier pigeon has saved, in peace as well as in war, by its swift and safe transport of critical tidings. Besides, one always admires a master along any particular line, and the carrier pigeon is a master in **homing.** The bee's homing (q.v.) is wonderful, but it works for short distances only. It cannot be compared with the pigeon's homing from hundreds of miles away. The general answer to the question, How do bees find the way back to the hive? is that they gradually learn the topography of the district, and that when they get near their own hive they are guided by their exquisite sense of smell.

But recent researches, those of Wolf in particular, go to show that bees have some special ' sense of direction ' located in their feelers or antennae—a sense by which they are able, as some men can, to enregister the twistings and turnings of their movements as they issue from the hive. This enregistration of movements that have been made connects the homing of ants, bees, and wasps with the homing of migratory birds, but there is this particular puzzle in the case of homing pigeons—that they come back to the dovecote from great distances, from places of which they have had no previous knowledge and from places to which they never travelled by their own exertions.

At important railway junctions, such as Wigan and Crewe, one sometimes sees piles of empty wicker baskets, which are the returned carriages of pigeons sent from the south to some place like Wick or Thurso. At these remote places the travellers are liberated, and the interest is to know how quickly they will find their way home. Sometimes one has the good luck to see a pile of baskets containing the pigeons on their way north to be liberated. We have peered through many a pigeon-basket in the course of years, and we must say that our glimpse of the travellers was always a happy one. They seemed to be in excellent form, and this pigeon-racing seems to us an aesthetic as well as a scientific form of ' sport.'

It will be understood that the educated homing faculties of carrier pigeons are based on the general homing capacity of migratory birds, which remains for the most part a riddle. A marked young swallow that left a Scottish farm-steading in late summer, and journeyed, perhaps along with some of its experienced kindred, to the Gold Coast or further south in Africa, will return in spring to the place of its birth. This has been proved satisfactorily for various kinds of

migrants. Terns taken from their nests on the Tortugas and transported in closed baskets on board ship into previously unvisited seas have been known in a percentage of cases to return home in two or three days from a distance of eight hundred or even a thousand miles. The homing of pigeons is a special case of the way-finding that is characteristic of migratory birds and exhibited markedly by a few other creatures. But we must not ignore the somewhat remarkable fact that the carrier pigeon is a domesticated variety of the rock-dove of our shore cliffs—a bird that is not a migrant in this country, but one of our residents. Even where it is not resident, as in Mediterranean countries, it has a short migratory range. Yet it is from this stay-at-home ancestry that the homer *par excellence* has been evolved.

The first light on the carrier pigeon's homing achievements is in the fact that migrant birds have this faculty in a high degree, not that this explains the nature and origin of the way-finding. The second light is in the fact of graduated apprenticeship. When a young pigeon is taken a mile or so from the dovecote, it rises in the air and circles for some minutes (five to fifteen) as if in hesitation; and it may take the wrong direction after all. On the second occasion the bird may be transported to a distance of a couple of miles, but there is little hesitation. After half a dozen lessons there is almost no hesitation, even at a distance of twenty miles. Gradually the distance of transport is increased to fifty or a hundred or more miles, and all hesitation vanishes. Moreover, if the apprenticeship is confined to the region north of the dovecote, its results work quite well if the bird is transferred to the south. Nevertheless, the success is greater when the distance is comparatively short; the optimum being under a hundred and eighty miles. It is also certain that pigeons lose themselves in a snowstorm, and similarly in a thick mist that is not confined to low levels. Other things equal, however, those homers are most successful that have had most experience of the country traversed. While there may be nocturnal flight, it is not generally a great success.

A third ray of light is in the fact of individuality, for some pigeons are much more successful than others. One of the individual factors is vigour and another is vision. These two qualities vary markedly from pigeon to pigeon, and from one stock to another within the carrier race. The carrier is the outcome of selection. A fourth clue is emphasized in Professor Rabaud's very interesting book, *How Animals Find Their Way About*, a thoroughly scientific treatment of the problem of orientation from a distance. He points out that the carriers often take far too long to their journeys when it is over new territory. Thus we read that eight pigeons, ignorant of the way, were transported from Antwerp to London, where they were released at 6 a.m. in fine weather. They circled about for a long time, and

then flew off, reaching Antwerp by seven in the evening. But the point is that they took thirteen hours to a journey which would normally have required no more than three. There are many facts of this sort, and they point to the conclusion that in difficult cases the homers make many tentatives. Rabaud concludes that 'good' pigeons, well trained, never return in a normal time when released in a region of which they have had no previous experience. Furthermore, 'those that do return are those that have flown about the most, having thus multiplied the chances of encountering clues—chances which diminish with the distance.'

Many pigeon-fanciers still believe that carriers are guided by a special magnetic or electro-magnetic sensibility, but this remains a mere hypothesis with many facts against it; and it is not to be considered seriously until it has been shown that the hints afforded by the senses known to exist are insufficient to furnish the necessary hints to the travellers. Pigeons have a visual sense of great acuity and range; they master the geography of their country and register its landmarks. Their inborn powers are remarkably amenable to education, and when they are transported in baskets to an unknown region they do their best—and we hear more about their successes than their failures.

We do not pretend that the homing of the carrier pigeons is a solved problem, but the solution seems nearer than it was; and the hopeful method is to make the most of sensibilities that are actually known to be present. While these are predominantly visual, there is no reason to reject the possibility of **kinaesthesia,** that is to say, a memory of muscular movements. Many explorers and mountaineers seem to register subconsciously how their bodies have actually travelled; and, in fiction at least, some blindfolded men and women remember how they were carried. We do not believe that a carrier pigeon enregisters much of its journey from King's Cross to Wick; but surely the supreme fallacy is to think of a highly endowed and specialized creature like a carrier pigeon as if it were oneself.

Birds in their Haunts

It would be useful to think oftener of even the restless birds as belonging, more or less, to certain characteristic resorts. To mention half a dozen examples, the storm petrel is characteristically pelagic, never coming to land except at the breeding season. For a great part of the year, the puffins, the gannets, the albatrosses, the guillemots, and so on, are also birds of the Open Sea. On the other hand, the gulls, the terns, the cormorants, and the rock-pipits are birds of the shore and the relatively shallow waters in the vicinity. For a great

part of the year, the cheerful oyster-catcher, which goes up the rivers to nest among the gravel, is a bird of the seashore, clever at making a meal of mussels and limpets, and many another littoral animal, except oysters. For the mountains and moorland we think of grouse and ptarmigan, golden eagle and raven, ' heather-lintie ' and stone-chat, and the water-ouzel or dipper on the foaming streams. The woods have their woodpeckers, wood-pigeons, and woodcock; the meadows their corncrake, lark, and pipit; the hedgerows their robin and wren, hedge-sparrow and chaffinch; the fresh waters their coot and moorhen, heron and water-rail, grebe and dabchick.

In many cases the bird's structure and habits are obviously adaptive to its particular haunt, and whether we regard the adaptation as a very direct result of use and disuse and of environmental influence (**the Lamarckian theory**), or as a very indirect result of novelties which were found to suit particular niches of opportunity (**the Darwinian theory**), we must consider the bird and its haunts together. Therefore let us give some instances in more detail.

SOME BIRDS OF THE SEA CLIFFS.—We wish to say a little regarding the birds of the sea cliffs as they may be seen in Britain at haunts like Handa Island, Flamborough Head, the Bass Rock, Fowl's Heugh, Ailsa Craig, Foula, and other ' bird-bergs,' as they may be called. These places have similar tenants, sometimes throughout the year, as in the case of cormorants and kittiwake-gulls; in other cases at the breeding season only, as in the case of guillemots and puffins. It is interesting to inquire what these birds have in common, how they are adapted to their haunts, and why they occur in some places and not in others. As to the last point, it is plain that the only sea cliffs that are of much use are those with *shelves or ledges* on which the birds can rest and nest, and that those are best which consist of stratified rocks, e.g. of sandstone or conglomerate, for these provide tier after tier of shelves for hundreds of feet, like a giant's bookcase. At the same time, many densely populated bird-bergs are granitic, as at the Bullers of Buchan; while others consist of some igneous rock like basalt. The *sine qua non* is the presence of shelves and nooks on which eggs can be laid.

Those who go down to the sea in steamers are familiar with open-water birds, often misnamed ' divers ' or ' dookers,' that swim on the surface in companies and take a quick header just when the vessel is upon them—curious mixtures of inquisitiveness and timidity. If these birds have sharp-pointed beaks they are **guillemots,** dark slate-grey or dark brown above, and brilliant white below. For the greater part of the year they are rovers on the Open Sea; it is only in spring and summer that they frequent the cliffs. They are true migrants, although there is no land which can be called their winter quarters. On the

surface they float buoyantly, or swim rapidly with their long webbed feet; under water they use their long narrow wings. They are not fond of flying on the Open Sea, but, if suddenly alarmed, they may take to wing and hurry spluttering over the waves. On the cliffs they shuffle about somewhat awkwardly, with the whole of the instep (*tarso-metatarsus*) horizontal, but they never lose their footing, and they are able to alight and to scramble on very steep gradients of rock. It is interesting to notice that the young guillemot stands with its instep almost vertical, as in ordinary birds. The splay-footedness is secondary.

When spring comes the rovers return from the Open Sea to the cliffs, which have been deserted all the winter. The reasons why so many hundreds of thousands congregate in one locality are simply that the number of suitably shelved sea cliffs is comparatively small, that the guillemots are scions of a gregarious stock (plovers), and that it is instinctive in migratory birds to return to the place of their birth. Of course, no cliff is of any use unless there is good fishing in the vicinity.

Guillemots have a courtship-ceremonial of their own—twining their necks together, nibbling at one another's plumage, interlocking their bills and swaying their bodies, bowing profusely, and wagging their heads from side to side. An individual bird is often seen running its bill down the front of its breast until it reaches the rock, then jerking it up again. This is like a male's performance; but, as the sexes are practically identical, it is difficult to tell what part is the cock's initiative and what the hen's response. They seem to be monogamous, and both parents share in brooding (as their worn patches show) and in bringing food to the young bird.

There are several points of great scientific interest in regard to the guillemot's egg. There is normally only one in the season, and in most cases there is not room for more than one at a time. It is held lengthwise underneath the body—the bird facing the cliff—and it is in part lifted on to the long feet, with its narrower end towards the tips of the toes. The shape is markedly top-like, and the utility of this, according to Darwin, is that if the egg be jostled by the wind or by the parent's feet, it does not readily roll on the ledge, but rotates on its short axis without moving from its position. It must be remembered, however, that if guillemots and other auks sprang from a plover stock, as the expert ornithologists tell us, then the top shape is a legacy. The original significance of the top shape in the plover's ground nest may have been to allow four or so eggs to lie within the limited space—the narrower ends pointing to the centre. If this be sound, we may still agree with Darwin that the shape has been retained in the auk family, even when there is but one egg, because

of the secondary advantage stated—that it prevents the egg rolling off the six- to twelve-inch shelf into the sea. It must be noted, however, that many eggs are knocked off, after all.

As to colouring and markings, the eggs of the guillemot probably show a greater range of variability than those of any other bird, and that is saying a great deal when we remember the heterogeneity in lapwing, black-headed gull, and cuckoo. In the large Fenton collection in the University of Aberdeen there are no two guillemot's eggs quite alike, and each is an individuality. The ground colour may be white, creamy, yellow, blue, or green; and the variety of spots, blotches, wisps, scrolls, and flourishes is endless. The egg moves in the oviduct before the paint is dry! It has been suggested that the individuality of coloration enables the mother bird to recognize her own egg; but this is highly improbable, especially as the extrinsic dirtiness of the egg often hides the distinctive features. What, then, is the biological interpretation? (1) If the guillemots and their relatives sprang from a plover stock, there might be exuberant variability to start with. (2) Since the eggs of guillemots and razorbills are very safe, because of their inaccessibility and because of the gregariousness of the birds, there may have been a suspension of the sifting action of Natural Selection, so that the spring of variability has overflowed abundantly. It is useful to look over a few hundreds of guillemots' eggs just to get a vivid impression of what variability means. If in the course of time there should arise a life-or-death demand for guillemots' eggs of a particular colour, e.g. like pudding-stone rock, there is abundance of material from which Nature might select.

The incubation lasts for about a month, and then begins the strenuous business of feeding the fluffy youngster, which eats heavily and sleeps much. The parent bird brings one fish at a time, and we have often watched a continuous procession, each bird with a sand-eel sticking out of its mouth. One of the incidents that give rise to squabbling is when a bird coming in from the sea has his or her fish stolen just before delivery. Then we hear the ' murre-murre ' rising into indignant protest and continued from shelf to shelf, as if many said: ' Not fair, not fair.' It increases in volume when a great black-backed gull sails about with evil intent. We may notice that when guillemots fight, whether with one another or against an intruder, they lunge with their bills closed, but open them just at the last moment, giving a strong bite or nip.

Both parents may be seen caressing their offspring, but after a month or so the time comes for initiation to marine life, and that requires firm measures. Before the young bird is able to fly it is jostled off the cliff into the sea, where it is at first greatly embarrassed. Sometimes the first step is taken in a gentler way, for good observers have

seen a parent guillemot carrying its young one on its back down to the water, and this is likely to be the case when the cliff is several hundred feet high. A third method of initiation is vouched for, that the parent seizes its offspring ' by the scruff of the neck ' and carries it down. In any case the young guillemots have to be accustomed to the sea before the time of migration comes, when restlessness seizes the myriads, and the cliffs know them no more for half a year.

First cousin of the guillemot and in a general way similar in structure and habits, the **razorbill** may be readily distinguished by the laterally compressed bill, with white lines on it, and by the strong white line running from beak to eye. The coloration is also different; the dorsal parts are black with a greenish gloss, the throat and fore-neck show velvety brown. The under-parts show a brilliant white colour as in the guillemot. On the shelves of the sea cliff the cousins usually keep more or less apart, living, as it were, in different streets of the same town. The razorbills prefer crevices and overhung nooks. There is considerable competition for suitable nesting-corners, and the birds tug furiously at one another with their bills interlocked. When a suitable nook has been secured it is jealously guarded, and trespassing is much resented.

There seems to be pairing for life, and it is highly probable, though unproved, that the same pair return to the same corner in successive years. Razorbills do not affect the profuse bowing that is seen among courting guillemots, but they are more vocal in their love-making, and show billing and nibbling caresses just like those of their relatives. These resemblances and differences between closely allied forms are very instructive, and we may cite a few more. In both cases the two parents incubate the single egg for the same time (thirty days), but the interior of a razorbill's egg-shell held against the light is greenish, whereas it is yellowish white in the case of all guillemots, except when the outside of the shell is blue-green. The variability of egg-colouring is distinctly less in the razorbill than in the guillemot, but there is a wide range compared with that of ordinary birds. In both types the young bird is fed on small fishes, but the guillemot carries one at a time lengthwise, while the razorbill carries several crosswise. Both kinds drink salt water. The razorbill's diving is uncommonly clever—a perpendicular disappearance; one gets a glimpse of the vanishing tip of the tail before one realizes what the bird is doing.

Belonging to the same family as the guillemots and the razorbills, the **puffins** (see Fig. 234) are highly individualized birds, marked by the stocky form, short neck, orange-yellow legs, and large, laterally compressed bill, brilliant in scarlet, blue, orange, and white. To watch thousands of them at midsummer on a breeding-cliff is to

enjoy one of the most cheerful sights in the world. In one haunt in the Hebrides, a few decades ago, their numbers were estimated by Professor Newton at three millions; but their ranks in most localities have been severely thinned since then, in spite of the fact that they are no longer much used for food. When alert they stand bolt upright and look as if they were resting on their tails. But this is an illusion, for it is only when they walk about or crouch for a spring that puffins plant more than their toes on the ground. When they are resting at their ease their pose sinks from the upright to the horizontal.

Puffins have short, narrow wings, but their flight is rapid and often zigzag. When they launch themselves from the cliff, head down, wings up, webbed feet spread out behind, they often describe a fine whirring sweep before they alight with a splash in the sea. They paddle on the surface with their feet, but they swim underneath the water with their wings. It may almost be said that they fly under water. Unless helped by a head wind, they find it difficult to rise into the air, and they often splash along for some distance before they are clearly launched in flight. Sometimes we see a flock of them wheeling in unison like shore birds, recalling the fact that auks are related to plovers.

Puffins are summer visitors and they prefer the top of the cliff where there is some soil, for they use their ' coulterneb ' and their toe-nails to make a yard-long burrow. The male is said to do most of the tunnelling, and we cannot wonder that he often takes advantage of a rabbit's labours. At the breeding season the males fight vigorously, flapping their wings and churning the water. There is billing and bowing between the sexes, and the head is often jerked upwards with the yellow mouth wide open.

The extraordinary bill is at its best at the breeding season, but it is the same in both sexes. It is covered with nine brilliant plates of horn which are shed later on, and since the plates are not replaced for some time, the bill in winter differs in size and appearance from the decorative summer form. As the plates correspond to reptiles' scales, the outer covering of which is periodically moulted, we see in the puffin's seasonal shedding of bill-plates a disclosure of ancestry —a harking back to the extinct saurian. While most of the auks lay their eggs on a bare shelf, the puffin lays hers in a rough grass nest at the far end of the burrow. If one tries to get at the bird, it is well to put gloves on, for the puffin bites shrewdly and does not readily let go. A terrier has been known to emerge from a composite burrow with three or four birds hanging on to him. There is a single egg, usually dull white (in great contrast to the guillemot's or the razor-bill's), and both parents brood for about a month. For as long again

the fluffy youngster requires to be fed, and we see the parents bringing in small fishes, several at a time, held crosswise in the mouth. As many as eleven have been counted in one mouthful, and there are often four or five. It is an old puzzle how the number of fishes is added to without the loss of previous captures; but perhaps the solution is to be found in the grip afforded by the tongue and by some spines in the mouth. It is often necessary to fly several miles to the nearest fishing-ground, but puffins have no lack of energy. On the bird cliff they seem to have a good deal to say to one another—purring, croaking, expostulating, soothing, and what sounds like laughing in their throats. It seems to us that they have four or five different words: the commonest is a long, deep, slowly rising 'awe.' At the end of summer, with one accord, parents and children forsake the cliffs and make for the open sea.

There are, to be sure, other birds of great interest on our cliffs, but perhaps there is sufficient illustration for our purpose in the guillemots, razorbills, and puffins which we have pictured.

Interrelations

The circle of a bird's life intersects many other circles. Thus there are **nutritive interrelations,** such as the check that carnivorous birds, notably hawks and owls, impose on the multiplication of small mammals, other birds, some reptiles and amphibians, many fishes, molluscs, insects, and worms. Similarly, there is the part that plant-eating birds play in destroying buds and young shoots, in digesting some seeds and scattering others. The list of **ornithophilous** flowers that are pollinated by humming-birds, honey-eaters, sun-birds, and the like is a long one, and several hundreds of tropical birds that habitually feed on nectar are concerned in pollination. In estimating from the human point of view the gains and losses involved in the nutritive interrelations of birds, we should try to realize the complexities of the case. A bird that does much damage in a fruit-growing county may be harmless or even useful elsewhere. A cormorant that takes its toll of trout may more than counterbalance this by devouring eels. The little owl, introduced from the Continent into Kent in 1874 and into Northamptonshire in 1889, has spread far and wide. It is destructive to songsters and young game birds, but it is beneficial in devouring injurious insects and small rodents. An estimate of a bird's value should also take account of activities throughout the whole year, especially when it has two main kinds of food, such as seeds and insects. Taking a broad view, we venture the proposition that the great majority of birds, probably 95 per cent, do far more good than harm; and that there is something to be said

for most of the small minority, like wood-pigeons and sparrows, that are, on the whole, prejudicial to man's interests.

The oscillations in the abundance of birds in connection with **changes in the food-supply** and in the number of enemies are of much interest. During a protracted plague of field-voles the number of short-eared owls has been observed to increase greatly; conversely, the shooting down of owls and the like is apt to be followed by increase of field-voles. Destruction of rabbits may force foxes to levy a heavier toll on pheasants; destruction of squirrels has been followed by great increase in the ranks of wood-pigeons, whose squabs are often eaten by the rodents. A great 'lemming year' in Greenland keeps the foxes well fed, and the ptarmigan increase in numbers. But next year, when the lemmings are scarce and the foxes many, the ptarmigan suffer in proportion. Rabbit warrens attract dor-beetles and other insects, and these favour the increase of certain birds. In scores of ways—often very subtle—the swaying balance influences the surrounding fauna and flora.

Careful watch should be kept on *changes* in the feeding habits of birds, for these may rapidly give rise to serious results. Thus an almost incredible change of diet made the kea parrot (see ODDITIES OF DIET) detrimental to sheep-farming in New Zealand, and large numbers of sheep have been destroyed in California of recent years by an exaggerated carnivorousness on the part of magpies. The ox-pecker of South Africa used to feed largely on the ticks picked from the hide of the rhinoceros; but as horses and cattle became common the bird turned to them, with unfortunate results, for troublesome wounds are often inflicted. Since the beginning of the twentieth century the herring-gull and the lesser black-backed gull have enormously increased their ravages on agricultural land in the north of Scotland (see HUNGER OF THE HERRING-GULL). In many cases a change of diet follows a rapid increase of numbers.

A few instances of **intricate interrelations** may be given. The mongoose imported to Jamaica to destroy rats turned its attention to ground birds, the result being an increase of injurious insects. As already explained, the disease of liver-rot (q.v.) in sheep is due to the presence of the fluke-worm (*Distomum hepaticum*) in the liver; the larval stages are parasitic in the small water-snail (*Limnaea truncatula*), whose numbers are reduced by such birds as the pied wagtail. Similarly, water-birds check the increase of various water-snails (*Planorbis, Melania, Isidora,* etc.) which are the vehicles of the young stages of the serious human parasite known as *Bilharzia.* Bubonic plague in India, due to *Bacillus pestis,* often begins in mills, where the workers eat their frugal meal in the courtyard. The 'crumbs' attract rats, in whose blood the bacillus is at home. A rat-

flea, with fouled mouth-parts, leaves the rat and infects man with its bite. But if there was a dovecote, whose inmates would promptly look after the crumbs, there would be fewer rats and less plague!

The distribution of the mistletoe is effected by the missel-thrush, which cleans off the viscid seed from its bill by rubbing it on to a branch, but there are even stranger cases. Thus Darwin tells of the large clodlet he took from the leg of a red-legged partridge (*Caccabis rufa*): 'The earth had been kept for three years, but when broken, watered, and placed under a bell-glass, no less than 82 plants sprung from it; these consisted of 12 monocotyledons, including the common oat and at least one kind of grass, and of 72 dicotyledons, which consisted, judging from the young leaves, of at least three distinct species.' Small animals also, such as water-fleas, water-mites, wheel animalcules, sponge-gemmules, and even small bivalves like *Sphaerium*, are often transported on the feet of birds from one pond to another.

The crocodile-bird (*Pluvianus aegyptius*), a kind of plover, picks parasites off the crocodile, and may even enter the yawning reptile's mouth to extract leeches. It is also believed to be of service as a sentinel. In the excavation made by the New Zealand 'lizard' (*Sphenodon* or tuatara) there is often a petrel, the reptile usually living on the right side, the bird on the left. In this curious instance there seems to be no partnership between the bird and the reptile; they simply share the excavation.

PARASITISM should be included among the interrelations. The most important **ectoparasites** are: (1) the biting-lice or *Mallophaga*, which feed on delicate portions of the feathers; (2) the quite unrelated true lice, belonging to the order *Hemiptera*, which suck blood; and (3) the skin-mites and scale-mites belonging to the Acarine order of *Arachnida*. Among **endoparasites** there are microscopic *Protozoa*, such as the Trypanosome found in the blood of owls, and *Plasmodium relictum*, the cause of avian malaria, which is carried by the gnat *Culex fatigans* and was used by Sir Ronald Ross in his work on malaria. There are also frequent representatives of the three great classes of parasitic worms. Thus the Trematodes may be illustrated by *Distomum macrostomum* in various Passerine birds; the Cestodes by *Taenia anatina*, the common tapeworm of the duck; and the Nematodes by the transparent *Trichostrongylus pergracilis* of the grouse. The three examples mentioned live in the food-canal, but other organs of the bird's body may be affected. The above-mentioned Nematode of the grouse may serve to illustrate the important point that numerous parasites may be present without doing any appreciable harm. Every grouse has hundreds of these minute threadworms, but a mutual *modus vivendi* seems to have been established between parasite and host. On the other hand, if the grouse should be enfeebled by

continuous bad weather, by lack of food, or by close inbreeding within a weak stock, then the parasites may multiply enormously and bring about fatal results in the body. It may be noted that birds often share a parasite with some very different animal. Thus some aquatic birds are the hosts of adult flukes and tapeworms, whose young stages are found in the fishes, or it may be in molluscs, which form a normal part of the bird's diet. It seems that some forms of pearls are produced in bivalves around the minute transparent larvae of Trematodes or of Cestodes whose adult stages occur in the food-canal of mollusc-eating birds. The eggs from the bird's parasites hatch out in the water and infect molluscs; but the linkages suggested are not as yet very convincing.

Some parasites occur in several different kinds of birds, but it is commoner to find a particular species of parasite in a particular species of bird. The discovery of a new bird usually means the discovery of a new parasite. This seems to illustrate the part that isolation may play in the establishment of a species. A bird's parasites are adapted to it and cannot readily pass to a different kind of bird. Moreover the infection of the bird is usually bound up with specific feeding habits. On the other hand, there is need of crucial experiments to test whether the successful transference of a parasite, say a Nematode, to a new host may not be followed by the modificational assumption of structural features at present regarded as inborn and specific.

ROADWAYS AND BIRD-LIFE.—It is a safe proposition that any change that is prejudicial to insectivorous birds is against successful agriculture, and this lends interest to a study by Miss Jean M. Linsdale on the influence of roads on bird-life. The paper refers especially to North America, but its relevance to Britain is plain. We select a few points. Roadside tangles afford much food and shelter; roadside ditches supply meat and drink; hedges and banks are useful for shelter and cover; many birds are attracted to roads where there are pools in which they can bathe; others find food in the horse-droppings; hedges, wild strips, and banks are common nesting-places. 'The set of conditions which go along with roads is such that a large bird population can live there.' The general moral is that extreme tidiness may defeat itself by lessening the shelter for economically useful birds.

On the other side of the account it may be noted that many birds are run over, and that many are killed by knocking against wires; but neither of these negative factors is very serious. On the whole, according to Miss Linsdale, the beneficial influences of roads more than offset the harmful influences, as far as bird-life is concerned.

THE EUROPEAN STARLING IN AMERICA.—Mr. Frank M. Chapman reports on the prodigious increase of the European starling in North

America. One hundred birds, by extraordinarily short-sighted enthusiasm, were introduced in 1890–1, and these are now represented by millions. From New York City the birds spread along the coastal region, and then began to penetrate the interior. In 1916 they had crossed the Alleghanies, and Mr. Chapman believes that they will surmount the Plains, the Rockies, and the Sierras, and establish themselves throughout the greater part of North America. Why should the starling have increased so much when native species have not, it seems, appreciably increased in any single case? The answer must be that the introduction of this alien meant opening up a field not exhaustively exploited. The starling found a niche of opportunity—'an ecological niche'—and prospered accordingly. Moreover, the starling is hardy, pugnacious, omnivorous, and prolific. It often has two broods in the year, and it is very successful in rearing them. What are the pros and cons of the hospitality that America has extended to the starling? (1) It is a very effective destroyer of cutworms, grasshoppers, and weevils, with few equals in the north-eastern United States. In this respect, then, it is highly beneficial. (2) On the other hand, the starling is very destructive of cherries, and to a slight extent it damages other fruits and garden green-stuff. In some places the size of the flocks is so huge that they drive away other birds and distinctly lessen the amenity of their haunt. On the whole the balance is in the starling's favour in America; and in any case the bird has come to stay.

A PLEA FOR BIRDS OF PREY.—We tend to sympathize with the weak rather than with the strong, but the strong have their value and deserve fair play. They may become the weak when man with his wits and weapons conspires against them. Our feeling and action in regard to them should be based on an all-round view. We should distinguish between humane *sentiment* based on impartially considered facts, and *sentimentalism*, i.e. exaggerated emotion based on ignorance, superstition, or misunderstanding.

Let us clearly understand, for instance, that killing birds of prey to increase the number of game-birds has consequences far beyond the end aimed at. Giving gamekeepers a free hand and free cartridges to kill what is labelled and libelled 'vermin' has often involved destruction far beyond the ranks of the proved enemies of game. Even from the narrow utilitarian point of view there is much to be said for the birds of prey. The honey-buzzard used to be familiar in England, but persecution has made it a rarity. The eggs are said to be worth £5 a clutch, and a pair of dead birds may fetch £40. At Geneva Major Anthony Buxton made the honey-buzzard's intimate acquaintance. Its menu consisted of 'wasps, hornets, frogs, and the fruit of lords-and-ladies, but, above all, wasps, and wasps at the rate of

1000 grubs at least a day.' Of course there is something to be said for wasps in their turn, but we are talking about birds just now. The highest appeal of all is that these birds of prey which are disappearing before Man—the crown of creation—are irreplaceable masterpieces of which we should be the jealous trustees.

FLOWER BIRDS.—It has been known for a long time that humming-birds sometimes pollinate flowers, just as bees and butterflies often do. But the researches of Otto Porsch show that there are far more flower birds than has been supposed, and far more bird flowers, too. In Java he found that over sixteen per cent of the families of flowering plants have bird-flower representatives. Fully fifty genera have species that are bird-pollinated. And the Javanese flower birds belong to twenty-two different kinds. Altogether Porsch finds evidence of over 1,600 tropical and sub-tropical flower birds, including only those that *habitually* visit flowers, carry pollen on their head-feathers, and more or less depend on the nectar of the flowers for their food and drink. With their intense metabolism and high temperature, birds usually require a relatively large supply of liquid, and watery nectar is a great help in tropical and subtropical countries. Moreover, nectar contains not only various sugars, forming a suitable food for strenuously exercised muscles, but subtler nutrition besides. Flower visitors belong to such families as the humming-birds and the honey-birds, but the habit has been acquired in no fewer than thirty-one different families. Of course some birds are more thorough-going flower visitors than others, but none are included in the list that are not more or less dependent on nectar; none are included that simply go to the blossoms to pick off small insects and spiders. The flower birds tend to be small in size, and strong in wing, able to flutter before or poise themselves on the blossoms. They usually have a fine-pointed bill, sometimes elongated, and a long, slender tongue, sometimes with processes like a brush. The bird flowers are usually conspicuously coloured (including pure white) and usually scentless. They produce large quantities of watery nectar, and many of them have special capillary arrangements around the mouth of the nectar receptacle, which tend to prevent wasteful overflow. Good examples are to be found among the following kinds: fuchsias, mallows, aloes, tropaeolums, verbenas, honeysuckles, gardenias, cacti, cannas, irises. They must be so built that the stamens dust the bird's head with pollen, and that the stigma of another blossom is in turn dusted. If the bird is a good pollinator, it will be, for several reasons, better than a bee; and floral variations that accommodate it on its visits will make for surer pollination and, therefore, for finer adaptation. It is not that this ' ornithophily ' is a new thing; what Porsch has shown is that it is much more frequent than was supposed.

GUANO ISLANDS.—Every one knows that guano is one of the most valuable fertilizers in the world. It is said to be thirty-three times as effective as farmyard manure. This is partly because it is so rich in nitrogenous compounds, and partly because they are in a form that makes them very readily absorbed as food by the roots of plants. The best guano comes from the dry and barren islands off the Peruvian coast that are washed by Humboldt's Current, a beneficent sweep of cold water that brings about a prolific abundance of marine life. Diatoms and infusorians are reincarnated in small crustaceans, which form the staple food of surface-swimming fishes such as anchovies. The multitudes of these fishes feed the clouds of birds that make the guano, which consists for the most part of the waste-products filtered out in semi-solid form from the kidneys. When this accumulates in a dry climate, not much changed by atmospheric influence, the result is a guano-bed. As Dr. R. C. Murphy tells us in his picturesque *Bird Islands of Peru* (Putnams, 1925), the chief guano manufacturers of that region are two kinds of gannets or boobies, a species of pelican, and a gregarious white-breasted cormorant of Antarctic origin that has established itself in dense colonies on the islands of the Humboldt Current. He claims the last—the 'guanaye'—as 'the most valuable bird in the world,' for guano spells bread. In one island the number has been estimated at over five millions, and it has been calculated that this population requires a daily consumption of a thousand tons of fish. There is no difficulty in regard to the supply of food, but the difficulty in years gone by has been the greedy and unscientific exploitation. If the removal of the guano and the disturbance of the nests is unsystematic and ruthless, the consequence must be a dwindling of the colonies to mere remnants and a stoppage in the supply of guano. It is gratifying to learn that the enforcement of a well-thought-out system of rotation—from island to island—has put an end to the short-sighted folly. Thus, if scientific counsel is obeyed, there will be no end to the production of guano.

The Chincha Islands, to the south of Peru, have the most valuable guano deposits because they are the driest. In many of the other islands the greater rainfall washes or dissolves away a good deal of the precious manure.

(1) Fish guano or fish meal made from the heads of cods and from fish refuse generally is a useful substitute for the natural bird-product; (2) there is also great value in the nitrates still available in huge unexhausted deposits, especially in Chile; (3) the twentieth century has seen the striking electro-chemical fixation of the free nitrogen of the air, and the using of it in the manufacture of fertilizers—a process anticipated in some quiet, secret way by leguminous plants, which

are able to fix the nitrogen of the air by means of their partner-bacteria. But bird guano still ranks above artificial manure because of ' the peculiar way in which its component parts are united, by the alchemy of the bird's intestinal tract, into a compound more easily absorbed by plants from the soil to which it is applied than any fertilizer synthetically produced.'

Achievements of Birds

We are apt to miss the truth about birds unless we think of them more warmly and generously, recognizing some of their achievements. Let us attempt this, even though our survey involves some repetition. There is surely something triumphant in the very being of a bird. As Ruskin said, the bird ' rests upon the air, subdues it, surpasses it, outraces it; *is* the air, conscious of itself, conquering itself, ruling itself.'

With what perfection do these swifts, hawking small insects, rush screaming through the air from earliest dawn to late evening, never resting save at the nest! What apparent ease marks their mastery of the air; with what economy of fuel is all their locomotion effected! A carrier pigeon has been known to fly at about fifty-five miles an hour for four hours on end, and a marked swallow is said to have flown from Compiègne to Antwerp, about 145 miles, in one hour and eight minutes!

Even a small bird like a chaffinch is believed to be able to get up a speed of about thirty miles an hour, and we have seen a great flock of wild geese overtake, pass, and disappear in front of an express train. For many birds fifty miles an hour is readily possible, and, as this is kept up for hours on end, we must call it a triumphant conquest of space. Birds began what man has so magnificently achieved—the annihilation of distance.

Large numbers of the Pacific golden plover winter in the Hawaiian Islands, which are about two thousand miles away from any continent. When spring comes they become restless, and it seems almost certain that flocks of them make a two-thousand-mile flight to Alaska. They stay there a few weeks, nest and rear their young, and then launch themselves again on their adventurous voyage across the trackless waste of seas. An observer writes: ' What at first might appear a physical impossibility—the two-thousand-mile flight of small birds across an ocean highway without a single landmark and with only the friendly winds to guide them, if, indeed, they utilize these as guides —is not only possible, but is accomplished annually by thousands of individuals, and apparently with no stops for rest or food.'

The swallows that spend their summer in Britain probably spend

their winter in western Africa, and it is a satisfaction to know with certainty that a swallow, marked in the north of Scotland as a youngster, returned the following spring, not merely to the same parish, but to the very farmyard of its birth. A similar return to the old homestead has been proved for the house-martin and the stork, and it probably occurs in many instances. It shows a triumph of way-finding.

From their nests in the Tortugas Islands eight terns, or sea-swallows, were taken in hooded cages over four hundred miles into the Gulf of Mexico, and liberated where no shore was visible. On their release all the birds with one exception started eastwards, for home. One headed west, in the direction in which the steamer had been going, but after flying for about two hundred yards, it turned suddenly and started east. They had a strong head wind against them throughout the first day, but two of them returned in safety to their nests. Many similar experiments have been made, and, explain it who can, it is quite certain that these untrained terns can return across the apparently trackless sea from distances of 800 to 1,000 miles.

On their steamer transport from their nesting-places they were kept in hooded cages and well fed with minnows; they were sometimes liberated at night; when they were taken northwards they were in entirely new waters, for the Tortugas mark the northern limit of their migratory range; they had often to win their way home through rain, haze, and cloudy weather; and yet the big fact is that in a certain percentage of cases, *home they did win*. Although we can offer no explanation, we have here a triumph of homing.

On a long sea voyage many have spent hours to good purpose in admiring the sailing of the albatross through the air—a puzzling kind of flight exhibited by some birds with a large wing area in proportion to their size. From the top of a cliff overlooking the sea one can often watch the 'sailing' of gulls, a prolonged locomotion without any visible strokes, nothing more than a slight change in the tilt of the wings, which are held out taut. The bird is taking advantage of currents, for sailing in the air, like sailing on the sea, is possible only where there is at least a little breeze. The bird is for the time being a flying kite.

The albatross, whose great spread of wings usually measures about eleven feet from tip to tip, shows sailing best of all. Almost in the eye of the wind, but not quite, it overtakes the steamer, crosses with a graceful sweep in front of the bows, and, with the wind in its favour, meets the vessel, sails down one side, and turns again astern. So it continues, describing majestic ellipses, mile after mile; and for half an hour on end one cannot detect any real stroke, only regular changes in the poise of the great wings. The mechanics of this kind

of flight remain rather puzzling, but every one who has watched it knows it as a triumph of movement.

The woodcock probes for earthworms in the soft soil and feels what it cannot see; the woodpecker feels with its tongue for the grubs in the crevices of the bark; but touch is not a strong point with birds. Nor is taste, for birds are given to bolting their food on sight. Nor is

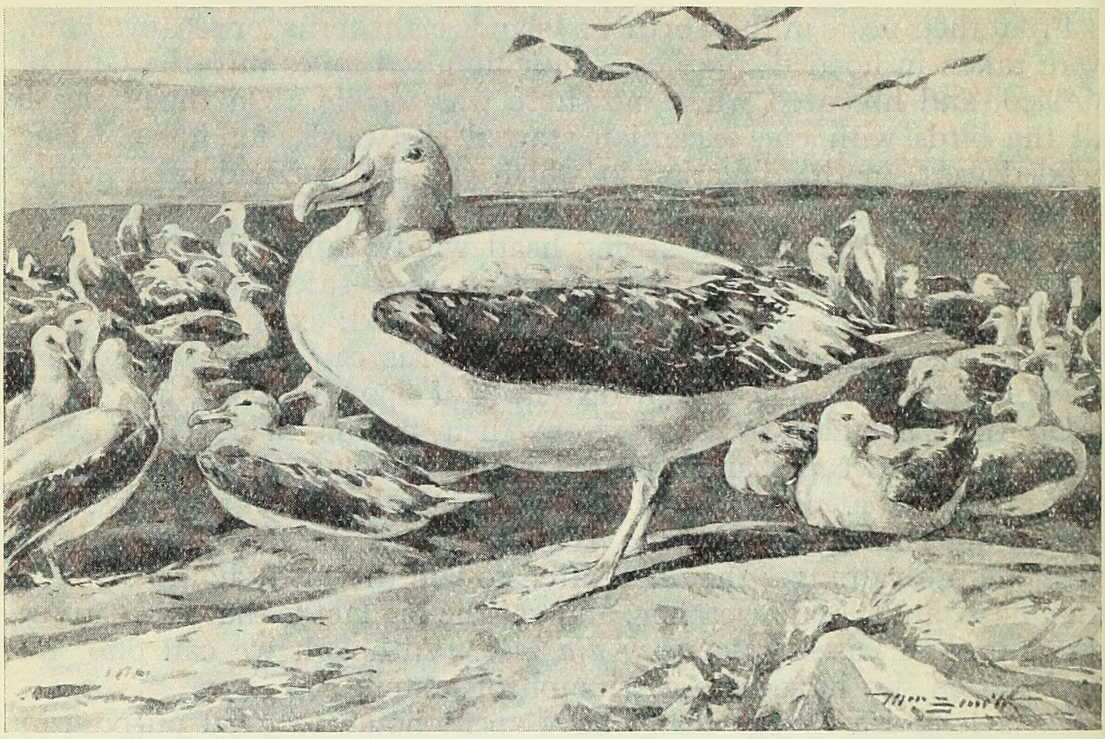


FIG. 249. AN ALBATROSS ROOKERY

smell, for, except in owls, night-hunting hawks, and a few others, it does not seem to be well developed. But how quick is their sense of hearing, and how perfect their vision! Let us take a few examples of vision.

Many people have made the experiment of throwing a piece of ship biscuit, no larger than a penny, into the wake of a steamer, amid all the whiteness of the foam, and watched the gulls competing with one another for the fragment. There is no question of finding or not finding the biscuit; the only question is—*Who first?* Not less remarkable, though less pleasant in a way, is the familiar sight of a carrion crow scouring the hill-side from a great height, searching for nestlings. More artistic is the hovering of the kestrel, the movement that makes sure, and the arrow-like descent on the hapless vole.

We need waste no tears, metaphorical or otherwise, for the victims of these birds of prey usually pass out of life instantaneously, some-

times in a few seconds. But what we were discussing was the triumph of vision.

With almost incredible quickness a crowd of vultures or the like will gather to a carcass, yet in many cases it is certain that each bird has its beat, and that the news spreads through the sky by B seeing A, who saw the spoil, and C seeing B, who followed A's swoop. For it is by sight, not by smell, that the vultures gather together to the carcass.

In endless ways birds manage to get over difficulties in the business of making a livelihood. A sparrow-hawk has been seen to lift a sparrow out of a flock on the ground without a pause in its lightning-like swoop, and a golden eagle does the same with a grouse among the heather. These are instances of great dexterity, but they are direct and straightforward. What seem to us more marvellous are gentler and subtler tactics, quite out of a bird's ordinary line of life. Thus, who can ever tire of watching the water-ouzel, or dipper, with its dark suit and brilliant white waistcoat, fishing for small water animals amid the splash and tumble of the mountain stream? It is a sort of aquatic wren, they say, whose ancestors left the crowded hedgerows and pegged out a claim for themselves. It would be a water bird, though in no way adapted to such a mode of life. It would walk along the bed of the stream, holding on to the stones. Having no webbed feet, it would use its wings for swimming, flying underneath the water. And all this has been achieved—so long ago that the water-ouzel has forgotten there ever was any difficulty about it; so long ago that all its doings under the water are marked by perfect finish. Must we not call this a triumph?

Equally diverse and perfect are devices of birds for solving the great bread-and-butter problem. The dainty humming-birds (see Fig. 238), with their long tongues, reach down to the nectaries of the deep flowers, just as some big moths are able to do. The woodpeckers often tap the sweet sap of the maple trees, and sometimes take more than is good for them. The New Zealand kea parrot has formed the bad habit of settling down on the loins of sheep and killing them by gouging into their flesh. The swifts and the swallows feed daintily on small insects; the gannet dives deep after fishes; the crossbill tears up the fir-cones for their seeds; the shrike makes a larder of small animals, hanging them on the thorns of the hedge; and so on for a thousand and one birds. But what are we to make of subtle cases like that of the Greek eagle, which solves the conundrum of making a meal of the Greek tortoise? This reptile is boxed in with bone above and below. It can draw in its head and its legs, and tuck in its short tail, and it is practically invulnerable. Who shall make anything of this creature whose body is his castle? But what the

Greek eagle has learned to do is to take the tortoise in its talons up to a great height and let it fall on the rocks below, so that the flesh is exposed. Many centuries ago, some books tell us, the Greek eagle thus killed the poet Aeschylus, mistaking his bald head for a white rock! Pray do not smile if we say that the tragedy was probably a pure accident.

As regards the care of the young among birds, let us take two extremes, each in its own way so admirable. The **mound-birds** of the islands of the Far East have in a sense no parental care at all; but it would be more accurate to say that it is all concentrated into the period before egg-laying. The parent birds combine in companies to make great mounds of vegetable matter several yards in circumference and several feet high, and in these heaps many eggs are laid. The vegetable material begins to ferment in the heat of the sun, and sometimes there are hot springs in the vicinity. In any case, a high temperature results—quite high enough for hatching the eggs without any patience of brooding.

Having laid their eggs, the parent birds hurry away, and it would be not only useless for them to try to stay, but quite impossible, for there is no available food for them in the regions where the mounds are built. The young mound-birds do not need their mothers, for they are born so far advanced that they are able to fly at once. Their whole babyhood has been, as it were, telescoped into the period before hatching, and they are the most precocious young birds we know. Here, then, we have a case where brooding would be both difficult and dangerous, and it has been dispensed with by a device which we venture to call positively triumphant.

The other case is very different—that of the hornbills of African and Oriental forests. When the time for egg-laying comes, the father and mother look out for a deep hole in a tree, choosing one with a narrow doorway. If the hole is too deep, they raise the floor; if it is not deep enough, they excavate a little. The mother bird gets in, and the father proceeds to narrow the doorway, using resinous material from the trees. The doorway is made narrow to keep out intruders, such as a monkey's paw; it is so narrow that the hen bird can shut it from within with her big bill.

The father bird has the task—a labour of love—of providing food for his imprisoned mate; and he brings her regular supplies of fruit, done up sometimes in quaint parcels surrounded by a stuff like sausage-skin. He puts these supplies into his mate's mouth through the open door, and after a while he has to feed not only her, but a youngster as well. Little wonder that he should by and by be worn thin—to a skeleton, some travellers tell us. Occasionally he dies of overwork, but even then the triumph over difficulties is not balked,

for other males are said to take on his duties. There is surely something exultant in life's defiant refusals to accept defeat.

For sheer defiance of difficulties in the way of nest-making is there anything to surpass the well-known sea-swift (p. 578) of the Far East? In the almost entire absence of any building materials the bird makes its nest out of the salivary juice of its mouth, which comes as near to making something out of nothing as we can well conceive. Some birds use saliva to help to make the mortar out of which the nest is built; others use saliva to make the fibres they work with more pliant; but the sea-swift makes its whole nest of saliva—a great triumph over difficulties.

As we have noted already, some deep constitutional disturbance in the cuckoo has upset the usual routine of mating, nesting, brooding, nursing, and migrating. One of the difficulties is that the full-grown cuckoos are not able to endure our country as long as the youngsters can. Their appropriate food of caterpillars is becoming scarcer, and off they must go, six weeks or so before their children, who are left to make the autumn journey without them.

This is the only instance in Britain where the old birds migrate in autumn before the young ones, and it is one of many peculiarities in the ways of the cuckoo. But all we are concerned with here is the masterly way in which the mother bird meets the grave difficulties of the situation. In most cases she lays her egg on the ground, takes it in her mouth, flies quickly down the hedgerow with her eyes wide open, and deposits it in the nest of some foster-parent.

Thenceforth there is no need for care; the foster-parents hatch the egg and feed the young cuckoo, whose appetite sometimes heavily taxes their energies. There are many difficulties not yet cleared up about the whole business, but the more we peer into it the more wonderful it seems. Thus the colour of the cuckoo's egg is very variable, and it often suits the colour of the clutch of the foster-parent. Often, however, the cuckoo's egg is glaringly conspicuous in the foster-parents' nest. Then there is the behaviour of the young cuckoo, which ousts the rightful tenants. It is not a very moral story, but who can deny the note of triumph?

There is an old saying that ' Man did not make society, but society made man,' and every one knows that one of the triumphs of birds is the establishment of **societies.** The rookery, for instance, is far from being a mere crowd or congregation; it is a large community with considerable power of unanimous action and with unmistakable conventions which come near to laws. Up to a certain point it is permissible to steal sticks from a neighbour's nest, but when that point is passed, tampering with a neighbour's nest is a social offence and punishable. We do not know what to make of the apparent

gatherings of rooks, the so-called parliaments, when the birds behave as if they deliberated and passed resolutions; but there is no doubt that there is plenty of talk, and occasionally concerted action. The three cleverest kinds of birds are the rooks, the parrots, and the cranes; and, though the rooks are alone among these in forming communities, the other two are distinctly social, and may combine both in work and in play.

How significant it is that pelicans will combine in fishing, arranging themselves in a wide semicircle and walking gradually towards the shore! How extraordinary are the drilling exercises that have been observed among the Antarctic penguins, and the games they play together! Best of all, in its suggestiveness for man, is the fact that small birds like cliff-swallows, individually insignificant, may have nothing to fear from a raiding falcon, whom they unite to mob. There are among birds many similar triumphs of sociality.

In the lower reaches of the animal kingdom many of the lessons of life do not require to be learned. The power of doing what is fit and proper is born in the creature, and this has its advantages, especially if the whole life is short, and if the young stages have to be passed in conditions quite different from those in which the full-grown creature lives. We mean that it would be rather difficult if a dragon-fly or a may-fly had first to learn the business of life under water, and had then suddenly to begin again and learn how to live in the air.

But when we come to birds it is very different. There are comparatively few inborn or instinctive gifts, but there is an extraordinary quickness of learning. This is the deep difference between the ' little-brain type,' like a bee, and the ' big-brain type,' like a crow. Professor Lloyd Morgan's chicks, reared in an incubator in the laboratory without any maternal education, were so shockingly ignorant that they did not know what their unseen mother's cluck meant when she called outside the door. Even when they were thirsty in their raw youth, they did not know what water was—though they might be standing in it. But when they happened to pick their toes in the water, a trigger was pulled, they recognized the water as something that satisfies thirst, and they did not forget.

On their second day of life the chicks stuffed their crops with worms of red worsted, but they did not twice indulge in a meal so unprofitable. They learned with prodigious quickness, and so is it with birds in general. They show triumphant power of educating themselves.

Art is the skilful use of materials, instruments, or parts of the body to express ideas or feelings. Art is significant form and movement, with a meaning behind it; and we venture to say that many things that birds do and make are on the threshold of art. Thus their **songs** are often much more than exuberant overflowings of love and

the joy of life. They are full of simple meaning, and full of those personal touches which art always shows. The same may be said of some of the **dances** of birds, and of their more elaborate aërial gambollings which partake of the nature of play. There is often a lavish expenditure of time and skill in making the nest not only an invisible shelter, fading into its surroundings, but a cradle beautiful.

There is triumphant skill in the hanging nest of the **weaver-bird** (p. 580), suspended at the end of a swaying branch above the water —the safe cup where the eggs lie being reached by a vertical, sleeve-like tunnel, up which the parent bird climbs; but we are inclined to go further in regard to the bower-bird's honeymoon bower, which is not a nest at all, but an arbour, and is deliberately decorated with brightly coloured objects—flowers, pods, feathers and even rags. Here we have to do with the skilful use of materials to express feelings, if not ideas. We are across the threshold of art. Life adds to its triumphs.

Many birds, like rooks and parrots, have very fine brains, and many birds show an ability to put two and two together in a novel way. We can get mentally nearer to birds than to bees, and we are less likely to make big mistakes in interpreting their behaviour. It seems fairly safe to say that, compared with ants, bees, and wasps, birds have far fewer inborn **instincts**, but much more power of acquiring knowledge or experience.

It is the mingling of instinct and intelligence that makes the behaviour of birds peculiarly fascinating. They have the perfect ease of routine without being enslaved by it, and, more than all other higher creatures, they are instinctively artistic in what they do. It is surely justifiable to say that in enjoying their triumphs we triumph also, being sharers in the life and spirit which bend matter to their purposes.

The Pedigree of Birds

The teaching of zoologists in regard to the origin of birds illustrates very clearly both the strength and weakness of evolution theory. On the one hand, in spite of the striking differences between the creatures of the air and the grovelling creatures of the earth, in spite of the practical absence of any connecting-link between scales and feathers, no competent zoologist has any hesitation in saying that birds evolved from an extinct reptilian stock many millions of years ago. This conclusion is based on the three familiar arguments of homologies, annectent types, and similarity in early development. A bird is obviously very different from a crocodile, and yet they share a number of radical features, such as a complex lower jaw made up of twelve bones, the articulation of this jaw with the quadrate bone,

a single condyle to the skull, a strong coracoid, an intertarsal ankle-joint, besides various minor features such as an ' egg-tooth '—straws which show how the evolutionary wind has blown.

Secondly, there is the fact that not a few of the extinct reptiles had become bipeds with hip-girdles in several ways bird-like, and that the earliest known fossil bird, *Archaeopteryx*, shows very many reptilian features, such as a long lizard-like tail and ' abdominal ribs.'

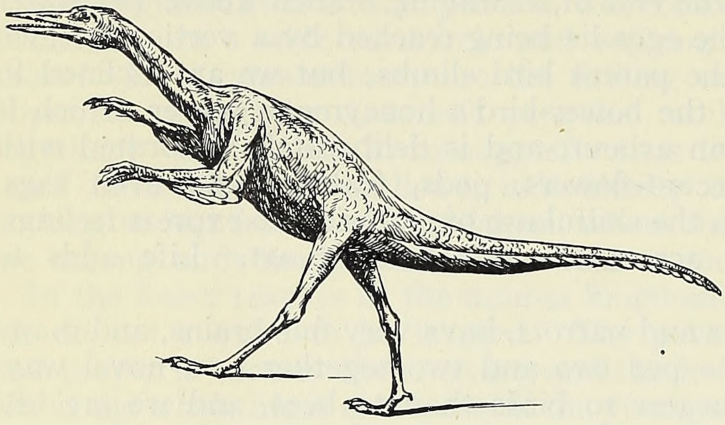


Fig. 250. Hypothetical Ancestor of Birds

Moreover, while there is no reason to suppose that the flying-dragons or *Pterodactyls* were directly ancestral to birds, they are of interest in showing that the problem which birds so successfully solved had been tackled by reptiles.

On a third line there are the eloquent embryological facts that show how closely alike birds and reptiles are in the early stages of their development. Internally as well as externally the egg of a goose is like the egg of a crocodile; they segment and proceed to develop in much the same way; they have the same ante-natal membranes—the amnion and the allantois; and for several days they journey, as it were, side by side, on the broad highway of Amniote development. Several days pass before their paths begin to diverge, the goose embryo showing, for instance, the beginnings of feathers. Here, then, we see the strength of the evolutionist position: anatomical, palaeontological, and embryological facts all point with emphasis to the same conclusion, that birds emerged from an ancient reptilian stock.

The weakness of the evolutionist position appears when we ask two questions—first, from what particular type or types of extinct reptile did birds arise? and, second, what were the factors that brought about the emergence? Our hesitation in trying to answer these two questions does not cast any shadow on the conclusion that Birds evolved from Reptiles; we are simply admitting that our knowledge of details is still in many ways vague. The encouraging fact is that it is gradually becoming less vague; and the last treatise on the subject, Heilmann's *Origin of Birds* (1926), starts off with the statement, somewhat optimistic we fear, that ' the evidences at our disposal are so manifold and conclusive that only a few minor particulars are still dubious.'

During the Mesozoic era all the modes of life illustrated nowadays by mammals were tried by reptiles, which had then their Golden Age. Some ran and others swam, some burrowed and others climbed the trees, and so on—but what interests most was that some were able to fly, namely the *Pterosaurs* or *Pterodactyls*. Some of these were no bigger than sparrows, but others had a spread of wing greater than

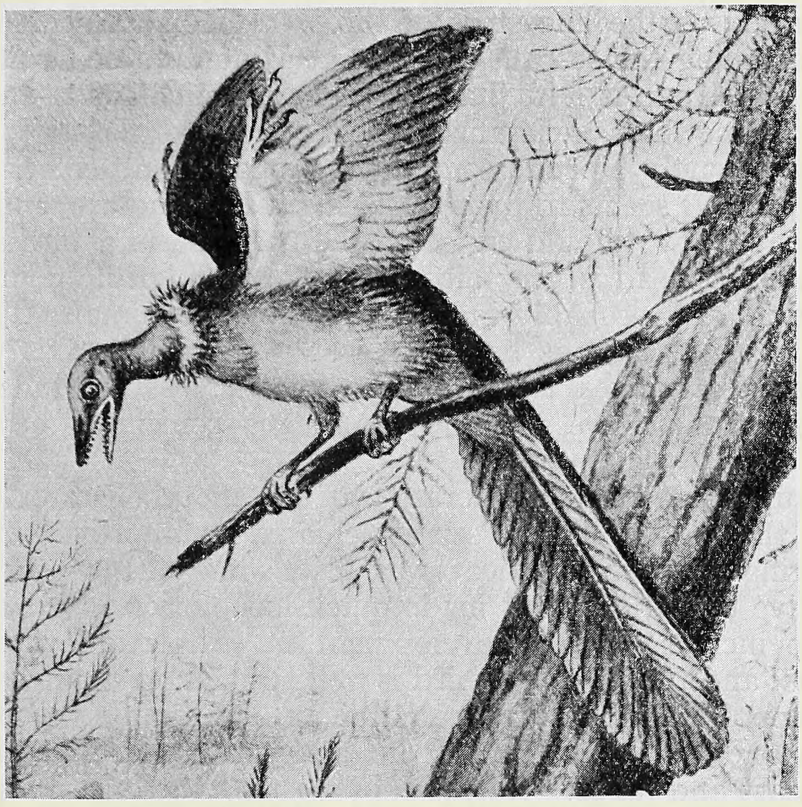


FIG. 251. RESTORATION OF *Archaeopteryx*

The figure shows the teeth in the jaws, hints of biserial tail-feathers, and the three claws on the outstretched wings, which are seen from the ventral aspect.

that of an albatross. They probably frequented the shore cliffs and caught fish in the sea. Their breastbone has some resemblance to that of the cormorant and the gannet. They had a long pointed beak as in birds, the same lightly built skull and pneumatic body bones, there is a keel on the breastbone as in flying birds, and there are other resemblances. Why, then, should we not look for the origin of birds among the Pterodactyls? The answer is convincing —the shoulder-girdle had no collar-bone, which every one knows as the characteristic merrythought of flying birds; the three digits which persist in birds are small in Pterodactyls; and the dragon wing

is totally different from the avian; it is a skin wing held out on the enormously elongated fourth finger. And so we might continue at length, referring, for instance, to the weak hind-legs, the hip-girdle not in the least bird-like, and the details of the skull quite different. There is no ancestry for birds along this line.

Heilmann's method in his vivid and learned book is to discuss critically what one might call the claims of various reptilian stocks to be regarded as the ancestors of birds. He disposes of one after another, including the so-called ' bird-like Dinosaurs or Ornithischia,' until only one group is left, that of the **Pseudosuchians.** These were primitive, somewhat generalized, scale-covered Triassic reptiles, potentially or partly bipedal, sometimes probably half-erect. A form like *Ornithosuchus* seems to have been ' light in structure and nimble in movement, as we should expect to be the case in a bird-ancestor, and the tapering head is very bird-like.' The hip-girdle points in the bird direction, and probably indicates a hopping animal. The scales are about twice as long as broad, and show a median axis with distinctly traceable ridges running sideways, suggestive indeed of a feather, especially if we imagine the ridges continued beyond the margin.

Let us suppose a great acceleration of the metabolism or chemical routine in these generalized Pseudosuchians, an improvement of the body-covering so that less heat was lost, some changes in climatic and nutritive conditions that made quick locomotion of great advantage, some increased brain-development in correlation with nimble movements: and the potential bird is well started on its upward path. Let us suppose that they became more habitually bipedal, with longer legs and a steadying hip-girdle, and with a correlated improvement of heart and lungs. Let us suppose that the ancestors of birds flapped their fore-limbs as they ran, and took running leaps which sometimes landed them on low-growing trees. There the first toe became a branch-gripping hind-toe; the parachuting habit grew strong; the head began to take on the duties of a hand. Scales became frayed out into feathers, and with the acquisition of this non-conducting clothing the animal heat was more perfectly conserved and the differentiation of a heat-regulating centre in the brain made the step to warm-bloodedness. Respiratory movements were linked to those of locomotion, so that the restless creatures did not readily get out of breath. Extraordinary muscularity, strong digestive powers, rich blood, quick heart-beats, growing brains, sharpening of the senses of sight and hearing, the enhanced potency of hormones to excite and to moderate, masterful emotions too—and behold the bird! The Pseudosuchians have long since passed, but they fulfilled their promise and gave us birds.

Behind all these detailed steps were the characteristic vital facts of *variation* and *struggle*. Novelties or new departures are facts to be observed in the present, and occasionally we can demonstrate their sifting or selection in the struggle for existence. There is no reason to doubt that variation and selection operated in the past; and this problem of the factors in evolution is a general one, in no particular way wrapped up with the question of the rise and progress of Birds.

Classification of Birds (after W. P. Pycraft)

I. **SUB-CLASS OF PIONEER BIRDS** (*Archaeornithes* or *Saururae*).—This extinct class is represented by two specimens, obtained from the same quarry of Upper Jurassic lithographic stone, at Solenhofen in Bavaria. They are usually regarded as two species of one genus, *Archaeopteryx* (see Fig. 251), and the two specimens are among the greatest treasures of the British Museum and the Berlin Museum—greatest treasures since they are connecting-links between ordinary Birds and Reptiles.

Archaeopteryx was a true bird with feathers, about the size of a crow. Among its most important features the following may be noted: (1) there is a long lizard-like tail of twenty vertebrae, bearing lateral feathers; (2) the jaws bear teeth, in sockets; (3) the palm-bones or metacarpals remain free; (4) there are three digits, all clawed.

II. **SUB-CLASS OF NEORNITHES,** with fused metacarpals and a short tail, and with no teeth except in a few extinct types.

Division A. **Palaeognathae,** with old-fashioned palate structure. The Flightless *Ratitae* and the *Tinamous*. The *Ratitae* include Ostriches, Rheas, Emus, Cassowaries, Kiwis, and the extinct Moas and Rocs.

Division B. **Neognathae,** with modern palate structure.

Legion 1. *Colymbimorphae:* Divers, Grebes, Penguins, Petrels, Albatrosses.

Legion 2. *Pelargomorphae:* Herons, Storks, Ibises, Screamers, Swans, Geese, Ducks, Birds of Prey.

Legion 3. *Alectoromorphae:* Game Birds, Cranes, Rails, Bustards, Plovers, Gulls, Auks, Sand-grouse, Pigeons.

Legion 4. *Coraciomorphae:* Hoatzins, Plantain-eaters, Cuckoos, Parrots, Rollers, Kingfishers, Owls, Nightjars, Swifts, Humming-birds, Colies, Trogons, Barbets, Toucans, Perching Birds or *Passeres*.

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ILLUSTRATIONS OF BIRD-LIFE

Cormorants

The stormy weather brings many cormorants to the quiet mouth of the river where they can fish in comparative peace. They sit on the shore in sombre groups, sometimes doing nothing but thinking, oftener not even thinking. Sometimes, however, they are preoccupied with their toilet, making a business of it, so to speak. They flap their wings dry with great vigour and preen them with great care. Sometimes they gape, as if amazed, but this is more probably due to an awkward fish-bone. They seem quite reckless in cramming their 'crop,' or throat-pouch, with fish, obeying a strong instinct to make hay when the sun shines. For many minutes sometimes they wrestle with a recalcitrant dab that is rather too strong and big for them, but they never give in. They batter the fish and seem to break its bones. A flat-fish is not an easy thing to swallow anyhow. When an intruder comes near the solemn row, sitting curiously erect, they set off, waddling inelegantly. They break into a little run and launch themselves with difficulty into the air. They usually fly low over the waves, with rapid, powerful strokes. They dive well, using both feet at once, and they can easily outswim a fish. Their usual custom is to bring their victim to the surface before swallowing. Handsome rather than beautiful, somewhat primitive and *farouche* in their ways, cormorants have a marked individuality. It has been possible to get nearer them through the observations of Dr. A. F. J. Portielje, of Amsterdam.

A cormorant paddling on the surface with alternate strokes of its feet reminds one of an overloaded boat, its body is so low in the water. But it can go much further, it can depress its body below the surface until nothing is visible but the head and neck. It does this when it is much perturbed, but Portielje notes that it adopts the same depressed position when it is going to snap at some small bird,



Fig. 252. Shag or Green Cormorant

like a swallow, flying low over the water. It should be noted that the cormorant does not usually show off much in broad daylight; it is most energetic in the early morning and before nightfall.

Portielje suggests that the frequent yawn-like gaping of quiescent cormorants, as they sit in the heat of the sun digesting their copious breakfast, may be a useful reflex allowing of evaporation from the internal lining of the pharynx, and thus tending to get rid of some of the surplus animal heat. One must remember that birds have no sweat-glands, and there is no doubt that they often suffer badly from the heat of the day. Yawning proper is a reflex expression of a need for more fresh air, as those familiar with churches and college lecture-rooms well know, but Portielje's idea is that the gaping of the

cormorants has to do with a reduction of the tendency to overheating. There is a rapid outflow and inflow of fresh air, and extra heat is got rid of from the whole area of mouth and pharynx. It might be compared to the dog's exposure of its tongue after a race, but the dog has sweat-glands.

Although the cormorants in the Amsterdam Zoological Garden are regularly and well fed, they indulge in a sort of diving and hunting ' play ' in the early morning and late afternoon. It naturally yields very little in the way of reward, but it is apparently great fun. It means obedience to a deeply rooted instinct. An interesting feature revealed by a study of this play, which is largely of the nature of ' sham-hunting,' is that the birds swim in a zigzag fashion under water and along the floor of their pond, just as if they were methodically exploring. This has been noticed in divers and some other birds, and it seems to be part of the hereditary or instinctive endowment. It has a *prima facie* appearance of intelligent planning, but it is more probably obedience to an inborn rule of behaviour. On the other hand, when a cormorant keenly watches the rise of bubbles from the sediment, which may indicate the presence of an actual fish, and then acts on the hint, there is more than a dawning intelligence. Portielje tells how the cormorant learns to make the most of the keeper's distribution of the rations, and how cleverly it steals a fish just as a pelican is about to make a capture. They have their inborn rules of behaviour, but they are also plastic, and able to learn intelligently in the course of experience.

The cormorant's ordinary greeting or ' how-do-you-do ' is a cheerful ' chrochrochro,' but this softens with a tremolo into an affection-expressing ' chrohohohoho,' or hardens into an angry bark, ' krao, kra-a.' When we once disturbed a brooding mother on the shelf of a sea cliff, she struck with her bill and hissed violently; and this is the expression of anxiety. But Dr. Portielje has made a much more intimate study of the cormorant's vocabulary. Early in the year, when white filaments appear among the metallic black feathers of the head and neck, the female, whose every year is leap year, utters her invitation—an often-repeated vibrant ' chra-ho-ho-ho-ho,' with short vowels. The male draws near with mincing steps and swaying body, and says ' kra-orrr.' As he shows off his good points and begins to find favour in his lady's eyes, he becomes more cheerful and says ' chrrro-chrrro-chro-choro-choro,' or words to that effect.

Except that the male bird may be rather the stronger of the two, and may show more white filaments, the sexes are indistinguishable to the eye; but they are quite different to the ear at the courting time. A particular place is chosen, which is at best suggestive of a nesting site, and there the male brings gifts. With a quaint mingling of play

and ceremony, described in detail by Portielje, he brings pieces of stick in his bill and lays them before his desired mate. Professor Julian Huxley has well described the courting gifts of the great crested grebe. We are apt to think too simply of well-endowed creatures, for there seems no doubt that these 'gifts' are of the nature of symbols, suggestive of nesting material. In some measure —we do not know how much—the cormorants attach 'meaning' to these pieces of stick, and it is interesting to learn that the male will bring them to his mate, still desired, long after the nest is finished, and even after the nestlings have hatched out.

But there is much more in the male's courtship than the dignified bringing of gifts. One has only to look at a cormorant walking, to see that he cannot be expected to dance, but he has a peculiar hop of his own, and part of the performance is an often-repeated opening and shutting of the bill. A quarter of a century ago E. Selous gave a fine account of the courtship-behaviour of the shag, which is the cormorant's first cousin, but he assumed that it was the male bird that took all the initiative. Portielje has shown that in the case of the cormorant, the female plays a very active part. Not only does she toy with the gifts, arranging them as if she were about to build a nest, but she moves her wings rhythmically, spreads out her tail like a fan, curtsies with her body, plays coquettishly with her head and neck, and utters the 'cha-orr' cry.

After courtship has its reward the female builds the nest with the materials that the male collects; she does most of the brooding, but he takes his share; when she is brooding he often sits close by, keeping a keen outlook and resenting the approach of an intruder. At times he will play with his bill and with the feathers on the female's neck; and then he will go in search of a gift. The incubation lasts for twenty-four days, and the young birds are hatched out naked and blind. In about a fortnight they are covered with sooty down almost like wool. The first feeding requires to be done very gently, but later on the young bird plunges its whole head deep into the parent's gullet.

The Butcher-bird's Instincts

When Tennyson referred to the sanguinary aspect of the hedgerow, he was perhaps thinking of the 'larder' of one of the shrikes or butcher-birds (*Lanius*), which often impales its booty on a stout thorn. A young pheasant, a mouse, a large insect, and so on, may be seen hanging up in the larder, and the sentimentalists (those who indulge in exaggerated feeling based on misunderstanding) have referred to the 'shambles' as an instance of Nature's savagery or even cruelty.

No one, indeed, will attempt to depict the shrike as a gentle bird, but it is an absurd anthropomorphism to call it cruel. In many cases at least the victim is killed before it is impaled, and in many cases there is no impaling at all. Some recent observations by Mr. Alden H. Miller on American shrikes increase our understanding of the facts of the case. He watched young shrikes which were reared without any parental instruction and away from possibilities of imitation. He observed a generalized instinct (an inborn predisposition to a certain routine) to drag biggish booty along the perch until it caught on a projecting nail and could then be torn to pieces by the strong hooked bill. As is well known, the toes are not suited for tearing. It seems then that the dexterous impaling on a thorn is an elaboration of a more generalized instinct to drag the booty along until it catches on a projection. The use in both cases is that it makes dismemberment more practicable. It seems likely that the apparent ' storing ' is an instance of the common continuance of a food-capturing and killing instinct beyond the limits of immediate utility. It illustrates the biological tax on a ready-made cleverness. The creature may be unable to resist killing, though it has no longer any appetite for food. Now and again, of course, the so-called larder may prove useful; but it is said that in many cases the bird does not return to what it has hung and sampled.

Hunger and Love of the Herring-gull

One of the most careful observers of birds from the outlook of Comparative Psychology is Dr. A. F. J. Portielje, of the Amsterdam Zoological Garden, who has recently made a study of the herring-gull. We wish to refer to two or three of his results in illustration of the modern mood which has changed interesting pictures of animal ongoings into a veritable science—Natural History giving origin to Ecology.

The herring-gull (*Larus argentatus*) is on the whole our commonest gull, much commoner than the common gull (*Larus canus*). In some parts of the country the black-head (*Larus ridibundus*) is commonest of all; and when it loses its ' black ' head in winter it may be confused with the common gull, which it approaches in size. The herring-gull is like the common gull in being white below and French grey above, and in having white ' mirrors ' near the end of the outermost black pinions, but it is a much larger bird. At close quarters one sees the flesh-coloured legs—yellowish green in the common gull—and a splash of red near the tip of the lower jaw, which is well seen also in the lesser black-backed gull and some others, though not in the common gull. While every one knows the herring-gull in its adult

plumage at least, there are not many people who can distinguish our six commonest gulls at all stages.

Herring-gulls often catch living booty from the surface of the sea, but they are more characteristically jetsam-eaters. They forage between tide-marks and devour all sorts of creatures that are thrown up, from birds and fishes to clams and worms. They are very fond of starfishes. In their foraging they are often accompanied by other gulls and by hooded crows. When the sea is rough or the tide is full they rest in their companies, sometimes squatting, sometimes standing on one foot with their head to the wind, so that their plumage is not ruffled. Then we see them at their toilet, distributing over their feathers the secretion of the preen-gland, using their bills as brush and comb, and their toes as well.

We sometimes see flocks of several hundreds resting on sheltered fields some distance—half a mile or so—from the exposed shore. It is a very beautiful sight, but not altogether pleasant, for it may be that the habit of resting inland when the sea is rough and when the tide is full has led on to what has become in recent years an increasing menace in the north of Scotland—the invasion of the farmer's fields by herring-gulls. They sit on the harvest stooks and gorge themselves with grain; they work up the rows of turnips, gouging out the succulent pulp or making holes that are open doors to fungi and threadworms. They also dig up potatoes near the surface. From man's standpoint the increasing vegetarianism of the herring-gull is to be deplored. It has probably to do with an increase in numbers, but it also means that the birds have discovered a new kind of feeding-ground.

Deep in the human breast there lurks a feeling of resentment when natural events do not work out in man's favour. We applaud the herring-gulls when they follow the plough and dispose of large numbers of grubs, leather-jackets, and wireworms; we wink at the fact that they pick up earthworms and at sowing time grains of corn; but when it comes to plundering the stooks and spoiling the turnips—why, it is a badly arranged world! Yet, who put an end to the sea-eagles that used to keep a check on the young herring-gulls, who makes the peregrine falcon in most places a *rara avis*, who fouls the surface of the sea with feather-clogging, plankton-destroying refuse of oil-fuel?

Herring-gulls may sometimes be seen persistently treading or tramping the wet sand left uncovered by the ebb, and Portielje tells us that this expresses an inborn or *instinctive* mode of behaviour which justifies itself in exciting lob-worms and the like to come to the surface, just as earthworms do when the soil is vibrated. The custom is not individually learned, for it is exhibited by young gulls in the Amsterdam Zoo, where the sandy soil is dry and with no earthworm

burrows. As the tramping on the seashore is often rewarded, the custom is corroborated by success; but it is, to begin with, a hereditary predisposition. It is also exhibited by black-heads, wild duck, flamingos, woodcock, young swans, snipe, and by some other birds.

The herring-gull, like its smaller cousin the common gull, has the interesting custom which many of us must have watched, of letting a captured mussel or crab, or the like, drop from a height on the rocks below, so that the shell is broken. Our interpretation of this (in *Minds of Animals*, 1927) as probably taking advantage of an accident is entirely confirmed by Portielje. When there is considerable competition it is usual for a gull to hurry off with its booty; a difficult prize, like a mussel, a cockle, or a small sea-urchin, might readily be lost in mid-air; if it falls on rock or shingle it is broken and made more readily available; and some dim appreciation of the consequences leads to the formation of a habit, which may be imitated by others. That the appreciation is not a vivid understanding of a causal sequence is shown by the fact that the booty is sometimes dropped repeatedly on soft sand. On the other hand, we have seen corners among the low seashore rocks bestrewn with scores of broken mussel shells, indicating that some gulls are 'quicker in the uptake' than others.

Another instance of plasticity in the herring-gull's feeding habits is its persistent search for the eggs of terns, redshanks, peewits, and even pheasants. Far inland the gulls may be seen scouring a moor for eggs or young birds, and there are reliable records of their hunting young rabbits. There is no denying the struggle for existence; but we should like to consider the herring-gull's 'love' as well as its hunger.

THE HERRING-GULL IN LOVE.—On some exposed parts of our coast, where the sea is seldom quiet, there are crowds of herring-gulls that nest on the ledges of the cliffs and on the grassy slopes higher up, and they sometimes make the air noisy with their cries. In bad weather, when the birds are probably more than usually hungry, there is an almost continuous wailing, which makes one anything but cheerful. But the vocabulary is certainly not confined to the hunger-wail, there are at least five other words. Thus Portielje describes notes of defiance and challenge, of alarm and warning, of invitation and entreaty, of 'tenderness' and encouragement. All these can be humanly expressed in syllables and notes; but what is perhaps more satisfactory is the observation that the birds use the words consistently, and in association with particular attitudes and movements. There is no difference between the masculine and the feminine vocabulary.

To what in man do these cries of gulls precisely correspond? Not exactly to our words, for these are socially imitated sounds which

have come to have definite meanings associated with them, and are eventually used deliberately to convey tidings or to express emotions. They differ greatly in different races of the *Homo sapiens* species. But the cries of herring-gulls are not individually learned; they are instinctive, and they are the same for all. They correspond rather to man's laughing or moaning or shouting, and depend on hereditary predispositions. No doubt, since the bird is not an automatic machine, but a creature that garners experience, a particular sound like the alarm-note will gather associations around it and become, as it were, emphasized or more significant. A particular emotional cry uttered instinctively by one gull evokes or tends to evoke a similar emotion in the gull that hears it; and it has been noticed that birds are sometimes interested in sounds made by other birds or other kinds of animals. We are not at present speaking of true bird-song, which is a much more intricate expression of emotion, often advancing from a lower to a higher level in the individual lifetime, and often involving imitation.

The herring-gull usually lays its eggs in May, but as early as March, with the first hints of spring, there is a distinct change in behaviour. The birds become more active in their flight—always so masterly—and they have much more to say. There can be no doubt that hormones from the reproductive organs are distributed by the blood throughout the body and bring about a general activation. The males and females are alike in plumage, and there is no special sex-display. This may be associated with the fact that they are gregarious in their nesting as in their other habits. Large numbers of shallow and rough nests, built of grass, fibres, and seaweed, are found together in suitable situations, such as the ledges of sea cliffs, the grassy slopes above the rocks, and low islands covered with sea-pink. There is no trace of promiscuity, for the herring-gull is monogamous, for the season at least. In captivity, along with others of their kind, the two mates sometimes remain as particular companions after the breeding season is over, though they do not, of course, keep themselves to themselves in any stand-offish way. One must be careful not to argue hurriedly from observations made in 'zoos' on birds that have had their wings clipped, but there is no doubt that monogamy for the season is the rule in natural conditions.

In the Amsterdam Zoo Dr. Portielje noticed that the same pair of gulls occupied the same nesting-site in successive years; and this probably holds in some measure for the wild birds. There is no doubt that a colony persists in utilizing a particular locality year after year, and the tradition is so strong that they will continue doing so even when the character of the site has changed. Thus they have been known to nest on certain dunes for twenty years after these

had been planted with conifers, and had ceased to be very comfortable. The territorial sense is very strong.

About the end of March or the beginning of April the pairs of herring-gulls make for the nesting-places and fly about in a sort of play, crying ' Kli-au ! kli-au ! ' Then they fix on their sites and take possession, although there is no nest-making for at least a month. They establish a claim and resent intrusion with an indignant ' Hahaha ! hahahaha ! ' This taking possession is probably quite instinctive and not to be thought of as intelligent prevision. It is part of a constitutionally prescribed routine, and corresponds to the choice of territory which has been carefully studied by Eliot Howard for warblers and some other birds.

What is almost quite new to us is the next chapter, the disclosure of which we owe to Portielje's patience. It has to do with premarital suggestion or symbolism, and shows how misleading it is to think of birds in a prosaic sort of way. As we have mentioned, there is no sex-display on the part of herring-gulls, but there is an instinctive repertory of little hints. Thus the male will peck persistently at the ground near the chosen site as if he was collecting materials for a nest, yet without actually lifting anything. Or a female will peck persistently at the male's bill as if she were trying to awaken in him the instinct of bringing food to the future nestlings. Yet in neither case does it seem justifiable to credit the bird with conscious purpose. The suggestive actions may be purposive, but they can hardly be regarded as purposeful.

Sometimes it looks as if an instinct were seeking expression prematurely; thus the gull will move its wings and feet and bill as if it were arranging the materials of a nest, though there is no nest in existence ! It is probable that this apparently meaningless activity has what we may call suggestive value, helping to excite sex-interest and feeling. Another play, which has also been noticed in certain unrelated birds, is lifting twigs, fibres, grass stems, and feathers from the ground and then throwing them backwards over the body. Is this an anticipation of future nest-building, or is it, as Portielje thinks, something subtler?

These must serve as instances of the premarital behaviour of the herring-gulls in so far as that consists of instinctive symbolism; but there is also much activity of a simpler character—in pose and movement and cry—which expresses emotion and desire more directly. Eventually the lovers have their reward and begin to build the nest and to brood. There are usually three eggs, dark olive or pale brown, blotched with darker spots. The nestlings are covered with brownish or greyish down, variously mottled, and their large appetite keeps both parents busy for many a day.

The Drumming of Woodpeckers

In many ways woodpeckers are peculiarly interesting. Think, for instance, of their striking adaptations, such as the strong pickaxe beak, useful in making holes in trees, or the stiff feathers of the tail which serve as a prop when the birds are hewing hard, or the peculiar arrangement of the toes, two turned forwards and two backwards, admirably suited for climbing. Then they have very interesting habits, such as that of storing acorns in neatly made holes in trees, a device which has almost become an obsession in the California woodpecker. But we wish to say a little about the 'drumming,' which is so often heard, even when the bird is not seen. It is most marked in the greater spotted woodpecker, and seems to be a method of excited signalling, especially at the courting time. It is made by both sexes — a peculiar vibratory sound with great carrying power, for it can be heard from over half a mile off. It is usually regarded as instrumental 'music,' supplementing the woodpecker's laughing calls and other sounds which are obviously vocal. According to an old theory, the peculiar drumming is due to vibratory movements of the head while the beak is thrust into a cleft in the tree, but the generally accepted view is that the bird makes the sound by hammering on a branch with its beak, the movements being so rapid that the head 'presents a blurred appearance.' Now many people have seen the bird moving its beak up and down with great rapidity, but that is not incontrovertible proof that the sound is actually produced by the hammering. And the interesting heresy has been recently started by

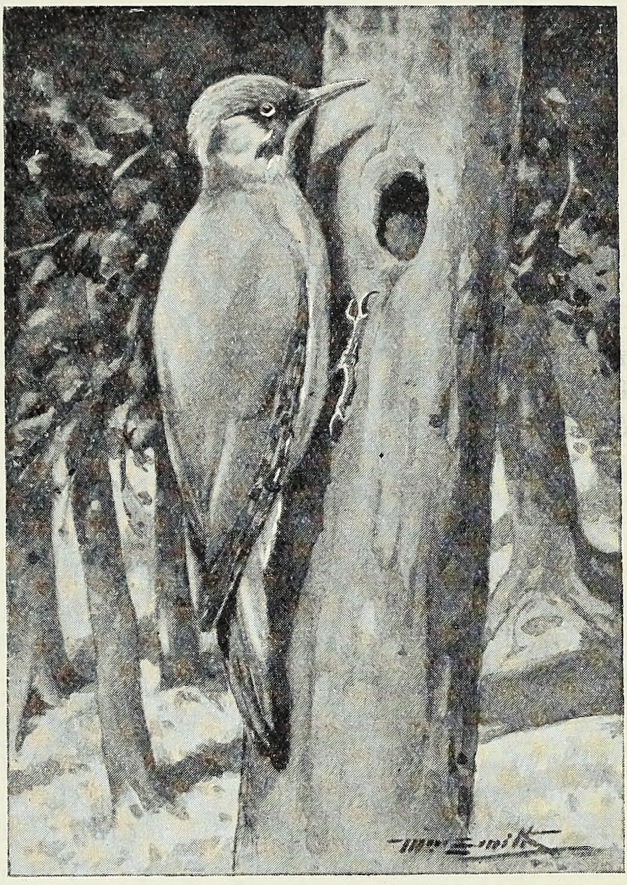


Fig. 253. Woodpecker

Sir W. Beach Thomas, a naturalist of distinction, that ' the sonorous outburst comes from the bird's throat, as does the cooing of pigeons, the hoot of owls, the purring melody of the nightingale,' or any other love-music. In short, he believes that the ' drumming ' is *vocal, not instrumental.*

A convincing observer, Mr. N. Tracy, who has lived for ten years among greater spotted woodpeckers, states the prevalent impression when he says: ' They generally seem to choose a perfectly dead branch, preferably one with a crack running down it, and the impact of the beak with the wood can be plainly seen.' But it must be noticed that Sir William Beach Thomas does not deny what is visible, namely, the rapid up-and-down movement of the head; what he doubts is that the beak strikes the wood and thus produces the noise like hammering. ' And while it moves its head, it makes a guttural call to its mate, just as does the nightjar moving its head from side to side on its bough.' But why, apart from healthy scepticism, should this observer doubt what seems, on the face of it, to be rather obvious? His answer is that it is impossible with so small and light an instrument as a spotted woodpecker's head and beak to produce by striking dead wood a sound which can be heard a mile off. Moreover, on a dead branch which had been for some days well drummed on, he found no mark of any kind. With this interesting scepticism well started, more observations must be made.

Before leaving the subject, we may refer to the instrumental or percussion sounds which are made by various birds. Very familiar is the ' clap ' of pigeons when their wings strike one another smartly above the back. A similar snap is produced by nightjars and by the South American manakins. Many people have heard in a ' zoo ' the castanet-like rattle which the white stork produces by clashing its jaws against one another. Mr. W. P. Pycraft in his invaluable *History of Birds* (1910) refers to the less familiar remarkable noise made by the black Penelope, a game bird of Guatemala, which ' occasionally pitches suddenly earthwards with outstretched wings, and produces a crashing, rushing sound, which has been likened to that of a falling tree.' Much discussed is the ' bleating ' or ' drumming ' of various snipe of both sexes at the breeding season. From a great height they descend with a prodigious speed, holding the tail fully expanded. The two outermost tail-feathers, peculiarly modified in structure, are held out at an angle to the axis of the body, and it is their vibration, as the air rushes over them, that produces the sound. This can be verified experimentally. The ' heather-bleater,' as it is sometimes called, may be said to have made a toy, if not a tool, of its tail.

The Common Partridge: A Bird of the Fields

This familiar bird is widely distributed in Europe and western Asia, and is resident in Britain. Although it is so palatable, it holds its own well, and for this there are three obvious reasons. In the first place, its subtle and very beautiful coloration gives it a cloak of invisibility, especially against the background of a ploughed field. In the second place, it can thrive on such a variety of food—shoots and leaves of grass and clover and weeds, tips of heather, bilberry and bramble, caterpillars, leather-jackets, grubs, and even green-flies. A partridge was even seen eating pears on a tree—a game bird! In the third place, it is very prolific, with ten to twenty eggs in the apology for a nest. Even forty eggs have been recorded from one nest, but this must surely have been a case of two hens. The mother bird sits very close, and her scent is suppressed during the incubation, the secretion of the preen-gland being probably in abeyance.

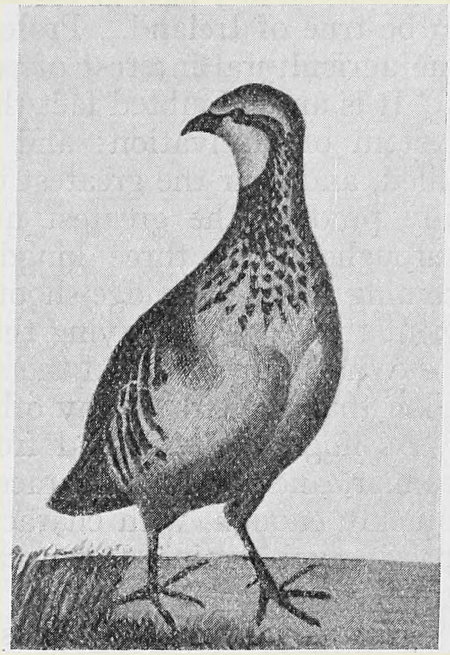


Fig. 254. Partridge

Another feature of survival value is the solicitous parental care. The young birds, themselves very inconspicuous in striped and spotted buffish brown, remain for a long time with the parents, who resent the approach of an intruder, and will defend their charges against a bird of prey or a dog, or even a man. A useful habit is lying squat and motionless when danger threatens, and there is probably value in the sudden cry and whirring of wings when the bird takes to flight just in the nick of time.

The partridge has been called the ideal game bird, for its shooting demands skill, the flesh is so palatable that we find it difficult to understand the complaint, '*Toujours perdrix*,' and the bird itself is, on the whole, the farmer's friend, for it destroys many injurious insects and does very little harm to crops. If the human population becomes denser, it may be found useful to rear more partridges, as might readily be done. And apart from increasing the natural food-supply, there are good reasons for wishing for a wider diffusion of wholesome luxuries. There is no reason why more people should not enjoy partridge and pheasant, salmon and oysters. Honey is another wholesome food that ought to be produced in much larger

quantities in Britain, and sold at a lower price. There is a good case to be made out for a democratization of wholesome luxuries—on an economic basis, of course.

While partridges sometimes occur on moors and heaths, they are distinctively birds of arable land. Thus they tend to increase in proportion to the area of wild ground that is brought under cultivation. Conversely, it is a bad sign when the number of partridges decreases in any part of the British Isles, and this unfortunately seems to be true of Ireland. Professor Newton spoke very emphatically of the agricultural interest of partridges:

' It is an undoubted fact that the partridge thrives with the highest system of cultivation; and the lands that are the most carefully tilled, and bear the greatest quantity of grain and green crops, generally produce the greatest number of partridges.' So many people throughout the three kingdoms are more or less affected by the coming in of partridge-shooting that the authority we have quoted went the length of saying that:

' What may be called the social influence of the partridge is greater than that excited by any other wild bird ' !

As might be expected from its habitat, the partridge is a great runner, and it prefers a race to taking flight. It can, of course, fly quickly enough, with characteristic alternations of rapid strokes and passive vol-planing, but it cannot keep this up for more than a short time.

Just as wolves form packs in winter, so families of partridges combine into coveys which move and feed together. The advantage may be that the approach of an enemy is more readily detected when there are many birds together, but we do not know that there is actual combination in defence or in ' mobbing ' an intruder. The coveys usually rest together at night, forming a circle on the ground, a gregarious habit called 'jugging.' But we do not know enough about this roosting. Pairing begins in February, before the coveys break up, and there are often combats between the lusty cocks, which rush at one another when challenged. But the tilting does not seem to amount to much, for partridges are monogamous, and the association of pairs is said to occur before the combats begin. Perhaps the rivalry serves to fan the fires of love, and it is interesting to hear that the females sometimes join in the excitement, occasionally in the fray itself. By the end of the month the covey splits into pairs, but it is not till the end of April or later that the eggs are laid in the well-concealed nest. All the brooding is on the female's part, but both parents are proud of the ' cheepers.'

When we try to describe the slate-grey plumage of the partridge, with all its vermiculations of black, its bars and streaks of chestnut

and buff, and so on, we discover what a complex dress it is—very beautiful in both sexes, and with minute differences between them. But when we have worked out our description, we find a bird that is predominantly grey, and then another that is mostly reddish brown, and again, another different from them all. The fact is that the details of the plumage not only change with age, but vary from individual to individual.

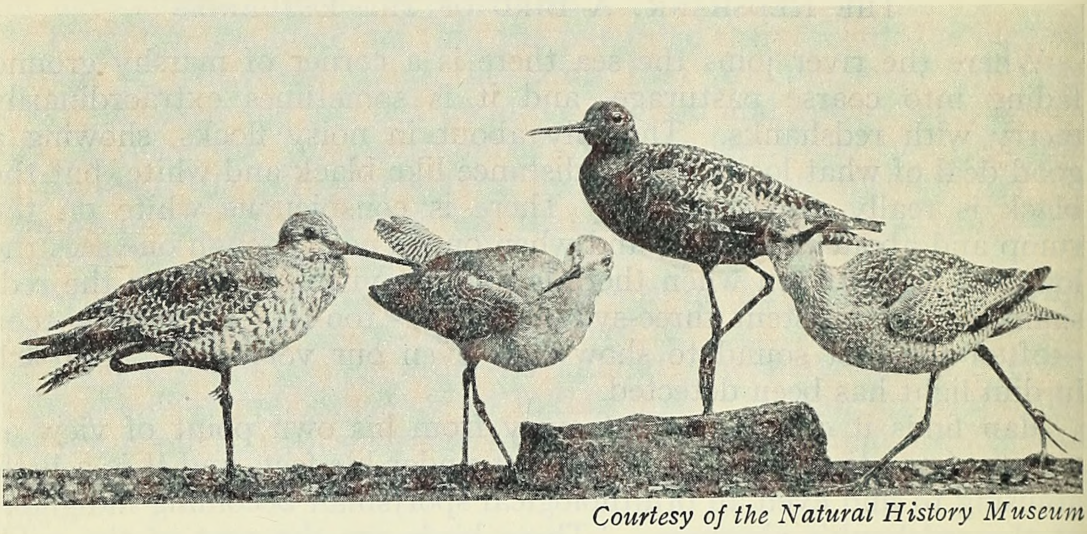
The Redshank: A Bird of the Estuaries

Where the river joins the sea there is a corner of marshy ground fading into coarse pasturage, and it is sometimes extraordinarily merry with redshanks. They fly about in noisy flocks, showing a good deal of what looks from a distance like black and white, but the black is really greyish brown. There is conspicuous white on the rump and about the wings, and when one is near enough one sees the long red legs. Even when there is nothing visible we know the redshank by the insistent three-syllabled call, ' too-too-eee, too-too-eee ' —often the first sound to show that even our very quiet approach in dim light has been detected.

Man finds it difficult to get away from his own point of view as crown of creation, with all things put under his feet, and it is a little amusing to find even an ornithological sportsman becoming indignant at the redshank's alertness. ' These birds are the pest of the wildfowler. Their mission in life, like the curlew's, seems to be to act like an automatic alarm to all other fowl, more especially to the flock of duck and widgeon for which you have been waiting for the past two hours, and are now punting towards with the flowing tide. Up gets one with his loud, piercing alarm-note, then another and another, till, finally, every redshank in the district is on the wing, calling lustily. The redshank is the biggest spoil-sport going.'

The redshank is the commonest wading bird in Britain, and it is widely distributed in Europe and Asia. How is it so successful, for it is commoner than ever? One reason for survival is the extraordinary wariness, and another is the greyish-brown colouring which harmonizes protectively with the grassy scenery. A third is the diet of common minutiae, such as sand-hoppers and worms on the shore, insects and their larvae on land. Redshanks will wade out on their stilt-like legs till the water floats them away, but they swim well and can rise from the surface into flight. Fourthly, their flight is swift and unpredictable; and, fifthly, a noisy band of them will combine to mob an intrusive hawk or any similar enemy. Another fact in their favour is the difficulty of finding the nest—for it is humiliating, the way in which one wanders round and round it, even within a small

compass. This is partly because there is often, though by no means always, an intertwining of grass stems into a canopy which hides the nest and the eggs from eyes looking down from above. The seventh —and we must stop with the perfect number—reason for the survival of the redshank is the strong **instinct** of the young birds to squat and lie quite still when their parents sound the danger-signal. Whereupon the parents insist to the human intruder that the youngsters are somewhere else altogether.



Courtesy of the Natural History Museum

FIG. 255. REDSHANKS

Redshanks are very beautiful birds, first cousins of sandpipers, and the sexes are alike in plumage. This makes it all the more necessary for the cock to tell the hen what a fine fellow he is; and he does this in various ways. Mr. Selous has described the sex-display, how the male waves and flutters his wings above his back in a very graceful fashion, meanwhile uttering a low tremulous note and shifting nervously on his feet. Sometimes the hen bird pays not the slightest attention; eventually, perhaps, she becomes interested, and love's labour is not lost. Mr. Selous points out that the posturing male is rather *behind* than in front of his desired mate during the rapid display, which may be all over in a minute, but ' his waved wings are, so to speak, all about him.' And as for the female, ' with an eye on each side of her small head, the slightest turn of this—and it is always in motion—would enable her to see the whole person of the male ' —the white rump, the silver-grey beneath the wings, and the coral-red legs. There seems no doubt that the banner-like waving of the wings is something in the nature of a proposal, and it is important to notice that the female often refuses to have anything to do with her suitor.

There seems to be real sex-selection. Selous writes: 'That he is addressing himself to the female and to her only, and that she knows he is, is obvious, quite manifest, not to be doubted by any one who has seen the thing.' But there is also keen and often prolonged fighting among rival males, and perhaps the experienced ornithologist whom we have quoted was right in thinking of a double selection, 'neither the handsomest nor the most vigorous *only* being chosen, but the handsomest among the most vigorous.'

There is another mode of courtship—a soaring flight, accompanied by a trilling song, which seems to us one of the most beautiful sounds in the year. The male soars and sings; he hangs in the air with rapidly vibrating wing-tips, or rises and falls like a fountain; he comes swiftly and diagonally to earth, and the simple music reaches its climax as he lands.

The brooding lasts for three weeks and the hen sits very close, sometimes allowing herself to be stroked, which shows that the self-preservative instinct is for the time being in abeyance. When the buff-coloured nestlings appear, the anxiety of the parent birds increases, but they never lose presence of mind. Their method is to sound the danger-signal and make themselves scarce. How far they understand their ruse we do not know, but their actions suggest almost irresistibly that they try to distract attention. Circumstantial accounts have been given of the 'accident-feigning,' when the redshank falls repeatedly on to one side and flutters with its wings on the ground. But one would like to have this scrutinized by critical eyes. Dr. F. M. Ogilvie gives a careful account of two redshanks which he watched shepherding their four fluffy young ones, four or five days old, down a furze-covered hill-side to the mere, which was about a quarter of a mile distant. 'Slowly the procession came down the hill, sometimes both redshanks leading and calling, sometimes one flying or running back, and apparently acting as a parental whipper-in.' The observer hoped to see the whole of the journey, but a glint from the barrel of his telescope betrayed his presence. Instantaneously the parents were off and the balls of down squatted. As he took one of them in his hand the parents stayed away, and it was not till he had replaced it and walked away that they ventured near—about half an hour afterwards! What life-saving caution!

The Water-rail: A Bird of the Streams

An old friend, who lives on Deeside near Balmoral, sent us a water-rail, inadvertently shot; and when we opened the box, not knowing what we were to find, our first impression was the familiar one, which is always new—the fact of beauty. Lying in the tissue-paper was a slim,

narrow-chested, lanky, short-tailed bird, nearly a foot long, with greenish-brown legs and red bill; but with such a dress! The upper parts are brownish, verging towards chestnut, and streaked with black; there is a crown of olive; the sides of face, neck, and breast are lavender; the flanks show conspicuous up-and-down bars of black and white; the under-parts are buff. This general description of the plumage sounds very heterogeneous, yet the dress is a unity, a 'creation' as they say, and also most admirably adapted to camouflage the bird among the reeds and the water-side herbage. The plumage, the same practically for cock and hen, is a very beautiful dress, but it is also a **cloak of invisibility.** In all probability the water-rail is commoner, even in the north of Scotland, than the records of its appearance would lead one to suppose. The date of our specimen's death—the end of February—would indicate that it is in part a **resident** bird. Some remain with us all the winter, but others are migratory; so that **partial migrant** is probably the most accurate description.

Some years ago we studied a water-rail that was caught alive in Union Street, Aberdeen! It was apparently on the migratory move, and beginning its journey afoot, not on wing. It was, we think, the most nervous creature we ever kept, and although we gave it the bath-room to itself and water to swim in, it remained anxious and troubled. It was infinitely graceful in its movements, walking delicately and then rushing, quiet for a moment and then thrusting out its head many times in rapid succession. It was like a spirit in prison, and as we could not tempt it to eat anything, we set it on its journey again, bidding it God-speed. It was not long before we heard that a water-rail had been seen running hard on the other side of the Dee about three miles away. But we are afraid that it would not travel very far afoot—especially in a bloodthirsty country like ours.

The water-rail's favourite haunt is among thick vegetation in marshy ground, or by the side of streams and lakes. Its long toes with their large spread are suited for walking on a treacherous substratum, but they are without the swimming membrane which is developed in the related coots and moorhens. Some say that the very narrow breastbone of the water-rail is an adaptation that favours rapid passage among the stiff reeds; and it is not unreasonable to suppose that in the course of time living creatures tend to pick out those habitats which are best suited to their anatomical peculiarities. Speaking for ourselves, however, we are quite unable to believe that water-rails became narrow-chested because they took to squeezing their bodies through the thickets of aquatic vegetation. That is surely putting the cart before the horse! It is much more likely, we think, that its ancestors varied constitutionally, that is germinally,

in the direction of being narrow-chested, and that their descendants became more and more at home among the river-side and lake-side reeds.

The water-rail is like its second cousin, the landrail or corncrake, in its swiftness of foot, and in its general unwillingness to take to wing. But both birds can fly fast and far when they get going; the short rounded wings strike the air with great rapidity. Swimming, which is only an occasional expedient on the corncrake's part, is habitual with the water-rail, and fine swimming it is.

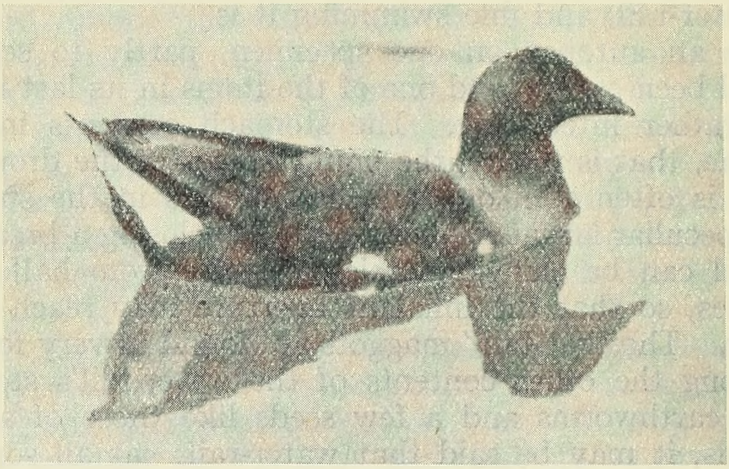
We made an autopsy on one specimen, partly to see what the creature had been eating, and one of the items in its last meal turned out to be rather interesting. The stomach contents included two **rat-tail larvae,** that is to say, the young stages of the drone-fly (*Eristalis*) which is often seen on dandelion flowers in the summer-time. These very peculiar larvae have a long tail enclosing a breathing-tube, and this tail can be elongated telescope-wise from half an inch to several inches, so that the inhalant aperture may reach the surface of the water. The ' rat-tail ' maggots are found in very foul stagnant pools. Among the other contents of the water-rail's stomach were three small earthworms and a few seeds like those of a grass. In general terms, it may be said that water-rails eat all sorts of small aquatic animals, sometimes with rootlets of watercress to supply vitamin C.

The keynote of the water-rail's life is secrecy. It shows none of the confidence of the water-hen or the coot; it is a master in the art of **self-effacement.** Not that the bird is cowardly, for Charles St. John tells of one that threw itself on its back in the snow and fought valiantly with a big gull, using beak and claws with good effect. But the point is that the water-rail is instinctively shy and secretive. A little flock may gather together in hard times, but the pair usually keep themselves to themselves. They say ' jik, jik, jik ' to one another, and Miss Turner records a continual ' purring ' at the nest. Most extraordinary, however, is a loud explosive scream, locally called ' sharming,' which is oftenest, though not always, uttered by the male, and at the breeding season. It is very unlike what one would expect from such a quiet and dainty bird. More in the picture, so to speak, is the love-making which has been described by Miss Turner and a few other privileged observers. The hen seems to take the initiative, for she circles gracefully round her mate and croons till he condescends to help her to dress the feathers on the nape of her neck. With apparent pleasure he passes them individually through his red bill. Later on, he takes some share in the brooding, and he also brings food to his mate as she sits.

The nest is made of reeds and sedges and the like; it is hidden away

among the aquatic vegetation, and it is usually very inaccessible. There may be six to ten eggs, creamy white with a few deep red-brown and bluish-ash spots. The young birds are quaint bluish-black balls of down that take to the water almost at once, but are guarded by day and brought home at night for a considerable time, till they are able to fend for themselves.

Here then we have a dainty, graceful bird, extraordinarily alert and



Courtesy of the Natural History Museum

FIG. 256. MOORHEN

active, very high-strung it seemed to us, that survives in virtue of its elusive shyness and its more or less inaccessible surroundings. It deserves all the protection and admiration we can give it, not only for its own sake, but because it belongs to a family without many British representatives. The British relatives of the water-rail (*Rallus aquaticus*) are the landrail or corncrake (*Crex crex*), several rare crakes (*Porzana*), the moorhen or water-hen (*Gallinula chloropus*), and the coot (*Fulica atra*). We have laid emphasis on the cursorial habits of the water-rail, swift on the wing though it be; and it is interesting in this connection to notice that some rails that are at home on oceanic islands have ceased to be able to fly. May evolution save *our* water-rail from flightlessness!

THE CAPERCAILLIE: THE COCK OF THE WOODS

We were walking quietly along by the side of a mixed wood of spruce and larch and pine when of a sudden we heard a great to-do among the trees, and then what seemed like a heavy body crashing down through the branches. We thought for a moment that two boys climbing for a nest had quarrelled, and that one of them had fallen, but before our thought was finished, a big bird, about a yard long, flew quickly across

the road, and we recognized the male **capercaillie**, the 'great cock of the woods.' We suppose that two of them had been having a scrimmage, but on other occasions we have noticed a single bird starting its flight in a noisy, clumsy way, as if it were too big for the branches. This seems strange in a forest bird, as the capercaillie certainly is by nature and upbringing. It frequents the northern coniferous forests from Scotland to Siberia, and it roosts in the branches. In spring and winter it depends mainly on the buds and young shoots of conifers, and, so far as this diet goes, it is no friend to the forester. In summer and autumn it feeds largely on the ground, on fruit and berries, insects and small fry.

The nest is usually made of pine-needles at the foot of a tree, the bird relying for safety on its size, and partly, perhaps, on the inconspicuousness of the brooding female. The young birds can fly soon after they are hatched, but late in the summer the mother is occasionally seen leading her half-dozen or so chicks, teaching them to pick up small earthworms and the cocoons of ants, and other minutiae of the forest débris.

In old days, when a great part of Britain was covered with forest, the capercaillie was widespread. There are some who say that its name, which varies not a little with the fancy of the speller, means the old bird or the old man of the woods. But as the forest shrank before axe and fire, the cock of the woods became scarcer. It disappeared so long ago in England that the date can only be guessed at; it survived in Scotland and Ireland till about 1760. But it had been becoming scarce for many years before that, for we read that one was sent in 1651 by the Laird of Glenorchy to King Charles II, who, being at the time at Perth, 'accepted it weel as a raretie, for he had never seen any of them.' Sooner or later, however, the capercaillie seems to have become extinct in Britain (though that is a little difficult to *prove*), and those that are now common in various parts of Scotland are believed by most authorities to be the descendants of a very successful introduction from Sweden to Perthshire in 1838. Capercaillies are successful colonists, and the females are usually the first to appear in a new area, as is not surprising since they are in a great majority. When they arrive in an untenanted wood they may consent to join the harem of a blackcock, with interesting crosses in consequence.

The story of the reinstating of the capercaillie in Scotland has been well worked out, and there can be little doubt that the spreading, whether a good thing in itself or not, is associated with a welcome fact —the re-extension of woodland. For just as it was the destruction of forests that led to the capercaillie's extinction (or, perhaps, approximate extinction), so it has been the restoration of forests (till the War, at least) that has encouraged its re-establishment.

The cock 'caper' is the largest of the grouse tribe, and a very handsome bird. Grey-black is his predominant colour, but to that must be added a metallic-green gorget across the breast, ruddy brown on the wing-coverts, a yellowish-white bill, a vermilion wattle above the eye, and after the second or third year a terminal white band on the tail. There are many minor embellishments besides. The female is a more partridge-like bird, predominantly reddish brown, and about ten inches shorter than her mate.

In one respect the capercaillie is very divergent from the red grouse, namely, in its relative unpalatability. No doubt our ancestors ate it when they could, as the bones in European 'kitchen middens' clearly show, but the suggestion of turpentine is too much for most modern palates. That is the natural result of eating pine-shoots and the like. The only caper we have tried was terribly tough: some etymologists say that capercaillie means the *horse* of the woods!

At the breeding season in spring the cock of the woods is very lusty, and, like his cousin the black grouse, though not like the red grouse, he is a thoroughgoing **polygamist.** Perched on a high tree, he shows off his good points, and indulges in extraordinary sounds and gestures. He challenges his rivals, and there are duels among the branches, the results of which are waited for by the timid hens below. We do not know that they care which of the two rivals is successful, but they seem to be wakened up a little by all the sound and fury. They answer back with excited croaks to the caper's caperings, and to what flatterers have called his 'song.' Mr. T. A. Coward, in his excellent *Birds of the British Isles*, quotes the truth-tellers who report having heard 'notes which reminded them of the squalls of fighting cats, of the drawing of corks, and the sound of grinding knives.' The voices of love are many and various!

Those who study modern slang may be interested to know that, according to the experts on bird-courtship, the first thing the caperer says is: 'Klick-kleck' (pause), 'klick-kleck' (pause), 'klick-kleck.' The sound is at first like the knocking together of two little sticks: eventually the klicks and klecks follow one another so rapidly that they become bell-like. Part two is like the drawing of corks, and part three is likened by the generous to the twittering of a bird, by the ungenerous to the sharpening of a knife—'sch-scht-ssts-pss-sch-scht.' However the 'song' should be written down, all who have heard it are agreed that the cock of the woods puts his whole soul into his passion, and becomes so preoccupied that he does not notice the approach of a murderous biped with a gun. This may seem a hard name to apply to a fellow-creature, but is it not dismally inartistic to kill a capercaillie at what is called his 'spel' or love-play? On the other hand, perhaps there is some excuse, for although our forefathers spoke of the

bird as having ' a gentle taste, maist acceptable,' it seems to us that a man must be desperately hungry before he would shoot a capercaillie, for his own consumption, at any time of the year.

The Woodcock: A Bird of the Woods

This indescribably beautiful bird is a resident in Britain, but its numbers are often increased in the wintry months by immigration from Scandinavia and other countries. Within the British area there is often **partial migration** from an exposed to a more sheltered haunt, as from Aberdeenshire to Ireland. There are probably increasing numbers in the country, and that is well, for the woodcock is one of the most palatable of birds, and in early winter large numbers are shot—by those who can.

We have called its beauty ' indescribable,' for while it is easy enough to admire such features as the neat, if somewhat dumpy, shape, the large, alert eyes, and the proportions of bill to head and of legs to body, the subtlety of the beauty is in the combination of colours, black, buff, chestnut, and grey, and in the variety and delicacy of the pattern. The woodcock is a good case in support of Sir John Burdon-Sanderson's view that our aesthetic emotion is always enhanced when we discern at the same time some *fitness*, for the plumage is indeed a cloak of invisibility. How inconspicuous the birds are among the withered wreckage of the wintry wood! How invisible the hen is when sitting on her early nest among the fallen leaves and dry ferns! The cock would be equally inconspicuous, for the sexes are indistinguishable, but he does not brood. As the coloration is so protectively inconspicuous, and as the bird keeps very quiet throughout the day, we do not see much of the subtler beauty of the plumage till our friend sends us a brace. It is a feast for the eyes as well as for the palate, and there need be no conscientious objections to shooting and eating woodcock, for the bird is at present holding its own well in Britain. Moreover, its flight when startled is swift and dodging, snipe-like in its turning and twisting, so that the shooting of woodcock is a test of the skilled sportsman.

The palatability of the woodcock may be due in part to its dainty diet, for it feeds mainly on earthworms. No doubt beetles, grubs, caterpillars, and slugs may be added, but earthworms form the most important part of the food. There is probably some inherent quality in the muscles of the plover-like birds that is pleasant to our taste, yet we cannot help thinking that the quality of the food has some influence. It is quite possible that subtle odoriferous substances pass along with the digested food into the blood and lymph, and thus reach the flesh. The zoologist Jaeger, who is remembered more for

his all-wool clothing than for his zoology, gave much time and thought to the study of odoriferous substances (*Riechstoffe*) in the animal body, and believed that they were far from being of such trivial interest as is usually supposed. It is well known that shrews are not eaten by cats even when killed, for there are odoriferous glands along each side of the body which give the little creatures a decided unpalatability. It would be interesting to make a careful study of the muscles of the starling to discover why it is generally avoided, for instance by a cat. And from the point of view of diet it would be interesting to contrast the flesh of the young rook, fed on insects, with that of the adult rook, whose diet is more heterogeneous. The young birds have often been eaten as rook-pie, even by the fastidious, whereas the adults are rarely esteemed. But this is a digression from a pleasant theme.

In connection with the woodcock's diet of worms, characteristic also of snipe, there are interesting structural adaptations. Not only is the bill long in both types, but the tip is innervated in a truly wonderful way. It must be one of the most tactile of all structures, and this 'touchiness' is obviously of great value in securing booty which is felt rather than seen. The woodcock probes systematically in the soft soil of likely places, and, as in the snipe, the tip of the upper jaw is mobile, and this will increase the range of the probing. In the woodcock about a third of the upper half of the bill can be bent upwards or sideways by means of two muscles, and the movement has been observed in aviary birds eating bread and milk. This unusual feature probably helps both in finding and in securing the earthworms. It is said that the bird sometimes stamps energetically, thus exciting the dull worms to movement.

Another anatomical peculiarity is that the large and lustrous eyes seem to be unusually high up and far back. This is due to a remarkable shortening of the base of the skull and a tilting upwards of the floor, so that the earhole comes to be below and in front of the anterior margin of the eye. The position of the eye has been interpreted as advantageous when the woodcock has thrust its bill deep into the soil, for it can look upwards and backwards and detect possible enemies such as owls. In any case the eyes are not much used in food-finding, and their large size may be interpreted as adaptive to shady woods and nocturnal habits. That there is good eyesight is plain enough from the way in which the birds can fly through a thick copse 'as if it were clear space.'

One of the thrilling chapters in the woodcock's life-history is the male's courting flight in spring. In the twilight, and it may be also at dawn, he repeats day after day a peculiar flight along what are called 'cock-roads.' According to Alfred Newton they generally

describe a triangle, the sides of which may be a quarter of a mile long. In this 'roading,' as it is called, 'the bird's appearance on the wing is quite unlike that which it presents when hurriedly flying after being flushed, and though its speed is great, the beats of the wings are steady and slow.' At intervals he utters strange croaking sounds, and there is also a shrill whistling which many believe to be produced mechanically—like the snipe's drumming—by the rush of air against certain feathers. For the woodcock Mr. Beebe figures the second, third, and fourth primary feathers of the wing as narrow and stiff. Besides courting in the air, the male also courts on the ground, strutting and showing off before the hen.

The four eggs are laid in a depression among withered leaves, and their coloration—yellowish ground with blotches and other markings of brown and grey—makes them very inconspicuous. We once saw a nest with white eggs—a very hazardous variation since it made them stand out very prominently. The nestlings are mainly buff-coloured, with longitudinal bands; and they might be described as cryptically dressed. There is no doubt that the mother can carry one at a time from danger to safety, and more than one good observer has described transport as a regular occurrence when the sheltering wood is dry and at some distance from the indispensable moist soil. Mr. Coward is no doubt right in saying that the method of transport is not always the same, but in the majority of cases the young bird seems to be held tight between the mother's thighs, and steadied occasionally by the bill. Sometimes, however, the mother's long toes take a grip; sometimes both bill and feet are used. However she does it, the mother does it effectively, as many observers can testify. Another device, self-preservative this time, is to feign death or to pretend lameness when the danger is extreme.

The woodcock is a highly specialized bird, as is shown by the peculiar tilting of the skull-base, by the mobility of the end of the bill, by the rich innervation of the tip, by the fine eyes suited to dim light, and by such peculiar habits as carrying the young. Thus *Scolopax rusticus* occupies a high place in the order of plover-like birds, in the family of plovers, and in the sub-family that also includes the snipe. It is the only species of its genus, so that, taking it all in all, we may call it a unique bird. Britain could do with more woodcock.

The Corncrake: A Bird of the Fields

Few people can boast of a close personal acquaintance with the corncrake. It is a past-master in elusiveness, one of the *cryptozoic* creatures. We made quite sure that it was lurking in a particular corner of the field, we saw its head peering out of the short hay; but

the next moment it craked from somewhere else. The fact is that it is always somewhere else. With its narrow body it threads its way among the pliant stems like a snake in the grass, and we found it hard work running the bird down. We were better pleased with one we surprised in a dry ditch by the roadside, for it gave up running after a few yards and lay low.

In some animals of relatively humble degree, among insects and crustaceans, for instance, a sudden change, such as being laid on the palm of the hand, often leads instantaneously to a sort of catalepsy, as if the body froze. Again, it is not difficult to put frog or snake, hen or guinea-pig into the immobile state called 'animal hypnosis.' But the corncrake's 'playing 'possum' is different from both of these. It seems nearer 'feigning death,' though we do not think it is that either. We say that it is different from catalepsy or hypnosis, because there is a strong suggestion that the bird knows all the time what it is about. It lay there in the dry ditch for several minutes, as still, to outward appearance, as if it were dead, and it even closed its eyes, but the moment we stroked its back with our hand it was gone.

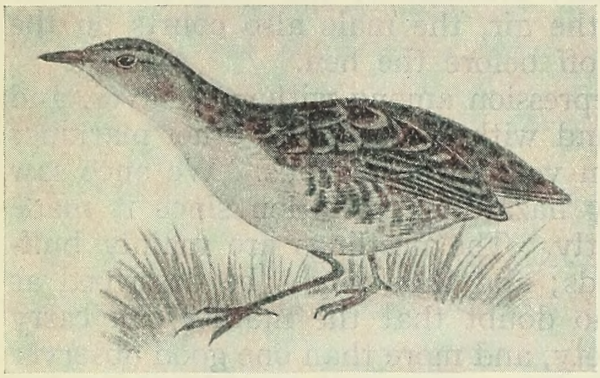


FIG. 257. CORNCRAKE

It simply vanished, as if our touch had let go the catches of a thousand springs. A muscular contraction used to be compared to a chemical explosion, but it seems even more like the sudden shortening of a spring that has been on the stretch.

The subtle brown and black and chestnut coloration of the corncrake's upper parts makes it very inconspicuous in certain surroundings, and the bird is possibly clever enough to be in some measure aware of this.

Perhaps it is from Central Africa that the corncrakes come to us every April or May. Some ornithologists think that they cross from Morocco by the Strait of Gibraltar to Spain, and thence through France to the English Channel and across. They make their way as far north as the Shetlands and the Faeroes.

Corncrakes can fly quickly and far, but it is likely enough that they migrate in a rather leisurely way, settling down to a run every now and then. When the male arrives he claims a 'territory,' and seems to spend a good deal of time and energy in informing other males of the fact and inviting females to join him for good.

It seems that for many birds the possessing of a territory or ' preserve ' counts for much. Mr. H. Eliot Howard has shown for warblers, for instance, that the males, which arrive first, take considerable care to select a suitable territory for mating and nesting. If it pleases the hen bird when she appears on the scene, she enters into the spirit of it, and will fight with other hens who try to intrude.

It looks as if the combats of rival males, in which corncrakes are not backward, using both feet and bill, were in some measure fighting for territory.

All through May the male corncrake has been craking, especially in the evening and early morning. Only for an hour or two about midnight does he rest his voice. After the eggs begin to be laid in June he ceases to call so often. It is a peculiar strident cry, which may be imitated by running a piece of hard wood down the edges of the teeth of a strong comb. Partly a challenge—' Keep out of my preserve '—it is also a love-call; and the male bird has a simple courtship ritual of strutting before his desired mate.

The supposed ventriloquism of the corncrake is almost certainly due to the bird's power of rapidly shifting its position among the hay or corn, or else to the presence of some rival which answers back from another part of the field.

The nest on the ground is a rough-and-ready structure of dry grass and the like; the seven to ten eggs are reddish white with spots of brown; the nestlings reveal the family—the rails—for they are covered with black down like young coots or water-hens. This is a good instance of the way in which pedigree is sometimes betrayed in early youth.

The mother bird sits so very close that she is not infrequently killed by the teeth of the mowing machine, and for this reason a hayfield is a more dangerous territory than a cornfield. For a few days after hatching the mother takes sole charge of the dusky brood, feeding them carefully on insects; after they are running about a little, the father is allowed to share in their nurture, and large family parties are sometimes seen.

From the farmer's point of view the corncrake is a very desirable bird, for it depends mainly on slugs and grubs and adult insects. These are becoming scarce by September, and the birds slip away southwards.

About the end of August, in preparation for the long journey, the corncrakes moult their feathers and get a fresh set. In both sexes the pinions are all moulted at the same time, and the birds are for ten days or so quite unable to fly.

This happens in some of the ducks and in other cases, but it is not very common. It would obviously be very disadvantageous for

ordinary birds; it is less serious for a quick runner like the corncrake or for an aquatic bird like a duck.

The only other remark we have room to make is that the corncrake has got an unusually appropriate technical name—*Crex crex*.

The Yellow-hammer: A Bird of the Hedgerows

One of the universal favourites among British birds is the yellow bunting or yellow-hammer, common on the hedgerows and among the whin bushes. In his nuptial plumage the cock bird is so brilliant that he makes us think of the Tropics, which we are not averse to doing on a chilly day in spring. The male shows much golden or canary yellow, with rufous brown and chestnut in parts, and with long white marks on the outer tail-feathers. The female is browner and more streaked. But every one knows the yellow-hammer, and the male's simple song: 'Little-bit-of-bread-and-no-cheeeese.' The call-note is a loud 'zik.'

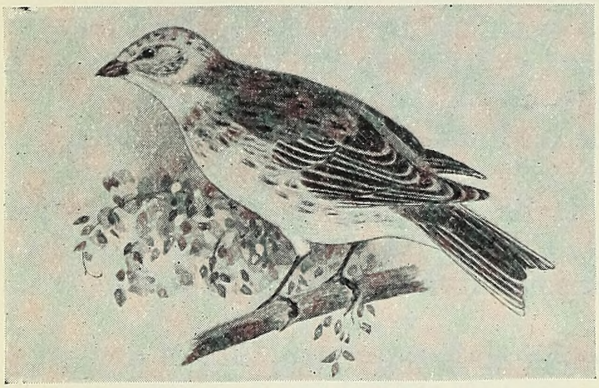


Fig. 258. Yellow-hammer

In summer they eat a good many insects and spiders; in winter they are more markedly vegetarian, searching in the fields for seeds, including corn, and in the hedgerows and common for small fruits. They are resident birds in Britain, but along the east coast their ranks are increased in autumn by immigrants from the north. Small bands congregate in winter, sometimes along with chaffinches and the like. They utter 'a liquid chirruping note' when disturbed.

The yellow-hammer has been recently honoured by being made one of the subjects for special discussion in Mr. H. Elliot Howard's remarkable book, *Bird Behaviour* (1929), one of the few important contributions that have been made to the biology or psycho-biology of courtship and allied activities in birds. We wish to tell part of the story.

During the winter months our yellow-hammers shelter in thick hedges or amid the furze bushes, and, as we have said, they are often in little flocks. Early in spring, however, the adult males segregate themselves and sit alone in prominent positions—one on a solitary oak tree, another on a furze bush, a third on a conspicuous mound. This is the male's selected territory or preserve, and it means much to him. He sits alone and sings a feeble song; at intervals he flies off to feed with his fellows on a field. He does not stay long with them,

however, for he seems to be anxious to get back to his solitary perch. Even in early days he behaves as if he felt that he had a prescriptive right to the chosen spot, for he is angered by any intruder. By and by he shows active hostility, and drives off any other male who comes near. This is the first chapter in the story, and it is one in which the female does not figure as a 'situational item.' Some of them do indeed come about, and one may even sit on the tree, but the male is not interested in them, nor they in him.

About the end of February a change occurs, connected partly with the weather without and partly with the hormones within. A female appears on the scene who is interesting to the male, it is hard to tell how. 'He flirts his tail, stretches his neck, raises his crest, and moves restlessly around her.' Previously vociferous, he now becomes quite silent. He chases the female and she tries to escape. They twist and turn; they come into contact and flutter together; the two of them may fall through the air. But they will not really pair for a month or two yet. The female may wander into other territories and interest other males; her prospective mate may follow to assert his rights, so to speak; but the quaint thing is that he soon pauses in his flight and returns, 'governed by an attraction stronger than that of his mate—the attraction of territory.'

Very interesting is the gradual change in the female's moods and ways. She may go off for days at a time, feeding and gossiping, but she comes back to her mate. They sally forth in opposite directions in the morning, but they discover one another in the course of the day and come back together. Gradually she makes a home of the oak tree, and welcomes her lover when he returns from the field. She restricts her wanderings, and she begins to drive off intruding females from the territory. The male comes to her assistance, and there is a lively scrimmage. More and more she falls in with the male's ways, acquiring his routine, partly by force of circumstances, partly by imitation, partly because she has become hostile to her own sex. Her constitution is slowly changing. But at the end of two months, or it may be only one, a new note is struck. The female enters the shelter of a thicket; she picks up a piece of dead vegetation, carries it to the tree, and negligently lets it fall. Next day she tears off shreds of bark and pulls up pieces of dead grass. In short, she is beginning to build a nest, and this synchronizes with the actual pairing, which is the climax of the third chapter in the story. Seven days after she picked up a piece of grass and let it fall again as of no consequence, she lays her first egg in the nest. The whole business is gradual, and like a slow awakening. Very remarkable is the way in which the wedded female will help to drive off intruding males, who are often strongly attracted to her.

The fourth chapter is brooding, and the two parents are companions. The male sings, feeds, makes short excursions, and fights his neighbours now and then. Mr. Howard detected a new, scarcely audible, high-pitched note, like that of a bat, which seems to tell his mate of danger. She broods, seeks food, preens herself, but especially she broods. When the young are hatched she collects food for them, and Mr. Howard noted that her temperament was much more nervous than her mate's. For when the observer stood by the nest the female would not give the young ones the insects she had collected. The male fed them without hesitation, but the female would only feed them through him. Another very interesting little detail is that while the male watches his mate busily collecting food for the newly hatched offspring, and may even follow her fussily, he does not take the hint for three or four days. Thereafter he brings the insects he has collected in his bill, and feeds the young ones regularly, also cleaning the nest. Such in brief is the story of the sex behaviour and parental behaviour of one of our common hedgerow birds, and a beautiful story it is, far more intricate than has been hitherto supposed.

Intricate and interesting, no doubt, but of what importance? Of great moment, even for a philosopher! For it is from studies like these—of the breeding and brooding yellow buntings—that we may discover the open secret that ' mind ' plays an essential rôle in ' life.' Mr. Howard is at pains to do justice to the physiological aspect of the story, such as the rhythmic changes in the bird's constitution, the rôle of the sex hormones, and the penetrating influence of the seasonal environment. But it is his conviction, and ours, that one cannot make sense of what happens unless one recognizes a correlated psychological story or aspect of the story, in which, for instance, an essential part is played by an imaging of the territory or home and by a retention and revival of this imagery. In short, ' mind ' unifies reactions.

The Owl of the Snows: An Arctic Bird

In a corner of our garden there is a tall and thickly branched, nowise beautiful, holly tree, and in its deep shade we often see a tawny owl (*Strix aluco*)—even when the ground is covered with snow. There he sits, looking big and comfortable, with his back pressed against the bole where a strong branch juts out almost at right angles. We often pass the time of day with him, but he vouchsafes no answer, though we have heard him use bad language to obtrusive rooks. Occasionally he opens his eyes and glares at us; sometimes he impolitely ejects a pellet; but he is not what could be called a responsive

bird. His real home is probably in the towers of the cathedral close by.

We have mentioned this tawny owl because in midwinter he looks as if he had conquered the cold; but the superlative instance of this conquest is the snowy owl (*Nyctea nyctea*) of the Arctic regions, an occasional winter visitor to Britain. It seems to us one of the most impressive of birds, sometimes standing nearly two feet high, the female larger than the male, and with a suggestion of strength in its half-hidden black beak and its feathered black claws. The plumage may be snowy white all over, or beautifully barred with brown. The yellow eyes gleam with fierceness. The bird is astonishingly handsome, though some critics say that its head is too round and that it would look better if its ear-tufts were longer. There is no pleasing some people.

A circumpolar bird, that rarely comes further south in winter than the north of Scotland, must have a good constitution. It is wrapped up in a thick soft quilt, like powdery snow, which must be an effective non-conductor, conserving the precious animal heat, and yet doubtless allowing of that circulation of warmth which health demands. Man is too apt to smother his animal heat. There is a touch of perfection in the feathering of the sole of the snowy owl's foot, as well as the upper surface—a feature also seen in the Scandinavian ptarmigan, the snow hare, the Arctic fox, and the polar bear. The snowy owl, with its feathered slippers on, is not likely to suffer from cold feet. Moreover, the whiteness of the plumage helps to conserve the animal heat, besides giving the bird a cloak of invisibility. This may be useful, perhaps, in the capture of lemming and ptarmigan, hare and willow-grouse in the north. 'It must be a bad moment for the ptarmigan when this white death with scorching eyes appears suddenly out of the blizzard, but perhaps twenty seconds will suffice for the encounter.' Like other owls, Nyctea flies almost noiselessly, so soft is its plumage; but we must not think of it as needing to be self-effacing except in the eyes of its victims. For the snowy owl has no enemies to fear, though it must be well hated. It keeps very silent as it flies, only occasionally uttering 'krau-au,' or some other such word, when it gets excited. What we may call finesse is illustrated when it goes fishing. Sometimes it waits by a hole in the ice and deftly snatches an unwary fish in its claws. At other times it flies low over the water, and with a sudden drop catches a fish, in osprey fashion, in its talons, without pausing on its silent course.

For eight months of the year the snowy owl's home is snow-covered and frost-bound. The nesting is in the short, nightless summer. The site of the nest is on a slope or bluff on the Barren Grounds or tundra; the indispensable requisite is that the place be dry and not

water-logged. The bird utilizes a slight depression among the moss and lichen, and scantily lines it with willow leaves and the like. There may be as many as ten eggs; but there are rarely as many nestlings. The first down plumage is sooty brown or sooty grey; the second is barred white. Perhaps there is some variability, for a good observer describes the young birds as like little bundles of cotton-wool. The mother owl broods and the father owl mounts guard. He darts at intruders, who cannot be frequent, 'with his wings whistling and his talons outstretched.' By and by he has a very busy time, for the mother and the family have to be fed on flesh. He does the foraging, and she apportions the meat among the children. It is said that the female bird becomes plump, while her husband becomes quite thin in the discharge of his parental duties. In any case, his and her loyalty is crowned with success. Whether it be in Lapland or in Alaska, the odds against a prosperous family are heavy; but the snowy owl wins through.

Even a museum specimen of a snowy owl commands our admiration, the creature is so handsome, strong, and full of fitnesses. But when we think of the bird in its native haunts, for most of the year the most inhospitable in the world, treeless, almost shelterless, wind-swept, blizzarded, and frost-bound, our admiration rises to homage; for we see the snowy owl as a symbol of the insurgence of life. We think of the months of darkness, occasionally relieved by the northern lights, of the intense cold which we get only a taste of in Britain, of the short commons when even lemmings are scarce; and we have a vicarious pride in the conquest of life over things. Our tawny owl in the holly tree has an air of nonchalant comfortableness which we admire on a bitter midwinter day—we spoke to him a few hours ago—but he is a plebeian compared with the aristocrat of the snows. Sentimentally we admire the snowy owl because it is at home, with such zest, in the Arctic regions, because it takes life gaily like its compeer, the Arctic fox. The snowy owl is defiant, and devoted to living dangerously. We suspect that it finds life rather slow when it spends the winter in the Orkneys and Shetlands. It has a strong body; we should like to see its brain; we feel confident that its mind is that of a gentleman unafraid. It is not related to the birds of prey, like the hawks, which have specialized on the robber-baron line; it is nearer to the quaint nightjars and goatsuckers. It is a ghostly wonder, this white owl of the snows.

Tailor-birds: Tenants of the Scrub

There are many marvels among birds' nests, but in some ways the nest of the Indian tailor-bird is most wonderful of all.

The first marvel is the perfection of the camouflage, which accounts

for the fact that though the pretty wren-like birds are familiar in many parts of India, the nest has been found by very few. It has been described in detail by Mr. Casey A. Wood, who was fortunate enough to be able to study it at leisure in Ceylon.

The nest is built among thick foliage and is pendent like the leaves that compose it. Sometimes one leaf is enough. Only the upper-surfaces of the leaves are exposed, and as the sewing does not usually kill them, they remain green. Thus the nest, whose cavity may be six inches long, is almost invisible, and it does not seem to last long after it has served the bird's purpose. What are often pointed out as tailor-birds' nests are really made by a red ant which fastens leaves together with glutinous silk.

The second marvel is that the female bird is a true tailor. She sews. With her sharp beak she makes a series of little holes along the edge of a leaf, and then she goes in search of the thread—which, to begin with, is supplied by spiders. Then comes the sewing, which Dewar describes as follows: ' One end of the cobweb strand she wound round the narrow part of the leaf that separated one of the punctures from the edge; having done this, she carried the loose end of the strand across the under-surface of the leaf to a puncture on the opposite side, where she attached it to the leaf, and thus drew the edges a little way together.'

In the nest Dewar described there was only one leaf, which was bent into a sort of funnel and lined with cotton. The lining is kept in place by being poked from within through punctures in the body of the leaf; and as the strain becomes too great for cobweb to stand, the edges are laced together with cotton threads. There are no knots; the strands of cotton are simply gripped by the stiff edges of the punctures.

As a triumph of manipulative skill the nest of the tailor-bird is of great interest, and one is glad to be told precisely how the work is done. According to Mr. Wood's observations there are four distinct processes —sewing, riveting, lacing, and matting.

(1) In a few cases the tailoress draws out a thread from the margin of one leaf and fastens it into another leaf—a sort of simple stitching.

(2) The usual process is to pull a shred of the cotton lining through one of the minute holes until the mass of which the thread forms a part is firmly drawn against the inner surface of the leaf. The external cotton then expands into a little button that holds the leaf and the contents of the nest in close apposition. There were seventy-five of these rivetings on the nest observed.

(3) Fine vegetable fibres may be passed from perforations on one leaf-margin to another and then back again—a kind of lacing. In one case a web-like thread was passed five times across the interval and then firmly fastened.

(4) ' The solidarity of the nest as a whole,' Mr. Wood writes, ' was

increased by the arrangement of the fibrous material in the lining, the coco-nut fibres, dried grass, and feathers being interwoven to form rings or bands that ran around and were fitted into the interior of the cornucopia, the cotton floss lining the cup cavity and padding the space below it.' The nest is a masterpiece of manipulation. But apart from the expanded button-like processes of cotton on the outside, there was not on the nest observed the slightest approach to making a knot on the thread of silk or cotton. Previous descriptions of the knots are probably based on a misunderstanding of the buttons. At the higher sartorial level reached by mankind, the sempstress, we are informed, never knots her thread; only men make knots.

These interesting tailor-birds, *Orthotomus sutorius*, are at home in Ceylon, Burma, and India. They are related to warblers and thrushes, but are somewhat wren-like in appearance and ways. At the courting time, however, the cock grows a remarkably long tail, which he flirts about gracefully before his desired mate. Both sexes are yellow-green. They frequent gardens, grassland, and scrub, and the elegant nest is rarely more than five feet from the ground. It is made by the hen only, but the cock helps in the brooding. One would think that his long tail must be rather in the way. He has to fold the feathers over his back, so that they almost touch his beak.

The tailor-bird's achievement has often been described with more enthusiasm than accuracy. We are told in old books that the tailor spins cotton into a thread, that it sews a dead leaf to the side of a living one, that the main method of nest-fashioning is an actual stitching of leaf to leaf, and that the thread is knotted at the end. The pronoun ' he ' is also used:

> *No tool had he that wrought; no knife to cut,*
> *No nail to fix, no bodkin to insert,*
> *No glue to join; his little beak was all:*
> *And yet how neatly finish'd. What nice hand,*
> *With every implement and means of art,*
> *Could compass such another?*

This expresses the right spirit, but we turn from it with pleasure to Mr. Wood's circumstantial detail. Truth is always stranger than fiction.

The Quezal: A Forest Refugee

Not many people know quezals, the characteristic birds of Guatemala. They used to be sacred and they figure on the postage stamps of that Central American country. They are among the most resplendent of birds, especially when they are alive, for they are cascades of

emeralds and rubies. They are also living marks of exclamation, for the male has tail-feathers that are sometimes over a yard in length.

Quezals, or quetzals, belong to the somewhat isolated family *Trogon*, marked by a unique type of foot in which the first and second toes are directed backwards and the third and fourth forwards, an arrangement well suited for gripping the branches. They are also famous for the softness and the splendour of their plumage and the thinness of their skin, which has been compared to damp tissue-paper—by enraged taxidermists no doubt. For they are most difficult birds to stuff, these thin-skinned aristocrats. We say 'aristocrats' because they are birds of long pedigree, of which the tail-feathers are symbols. There is a fossil Trogon in the Lower Miocene of France, but the living Trogons hide in the dense forests of Central and South America, Africa, India, and Malaya. Most of them may be interpreted as forest refugees who have got out of the bustle of the open country, and live very quietly among the trees, feeding mainly on fruits, but also catching insects on the wing. The nest is usually a hole bored in a decaying stump or branch. Quiet-living, easy-going, thin-skinned, old-fashioned birds, in whom beauty runs riot—such are the Trogons.

Quezals are the most splendid of all Trogons. They used to be called *Calurus resplendens*, rather a fine title, meaning the resplendently beautiful tail; but they now bear the name *Pharomacrus mocinno*, which seems less expressive. The body is about the size of a small dove, but it looks bigger than it is. For the head is crested and some of the upper tail-coverts in the male are greatly lengthened into iridescent emerald plumes. Those on our specimens are over two feet long, but Mr. Beebe speaks of three and a half feet. The plumage of the upper parts is a brilliant green with hints of gold, but on the breast and belly there is rich crimson. Very remarkable is a group of lance-shaped feathers which rise from the shoulders and hang over the wings, forming superb epaulets. But there is no use continuing. Before it is too late let us all enjoy a quezal. See Naples and die. Who can wonder that the bird was sacred to the Mayas, of whom the chiefs alone were allowed to wear its plumes? It is carved on some of the ancient monuments, and it is still, we believe, the national emblem of Guatemala. The early descriptions of the bird were so glowing that Willughby placed it in an appendix to his *Ornithology*, amongst others which he called ' fabulous.'

When admiration allows science a look in, our first thought about the male quezal is that his long tail must be very much in the way. But this is not borne out by those observers who have watched the living bird. In the first place, the quezal lives neither on the ground nor on the tree-tops, but on the branches half-way up. In the

second place, it does not climb or clamber, but looks about for a ripe fruit and plucks it off in its bill without stopping in its quick and straight flight. There are four elongated tail-feathers, but only the two central ones are extremely long, and they are whisked deftly about as the quezal flies. The female, though brilliant, has not these elongated streamers; and it must be granted that they would be

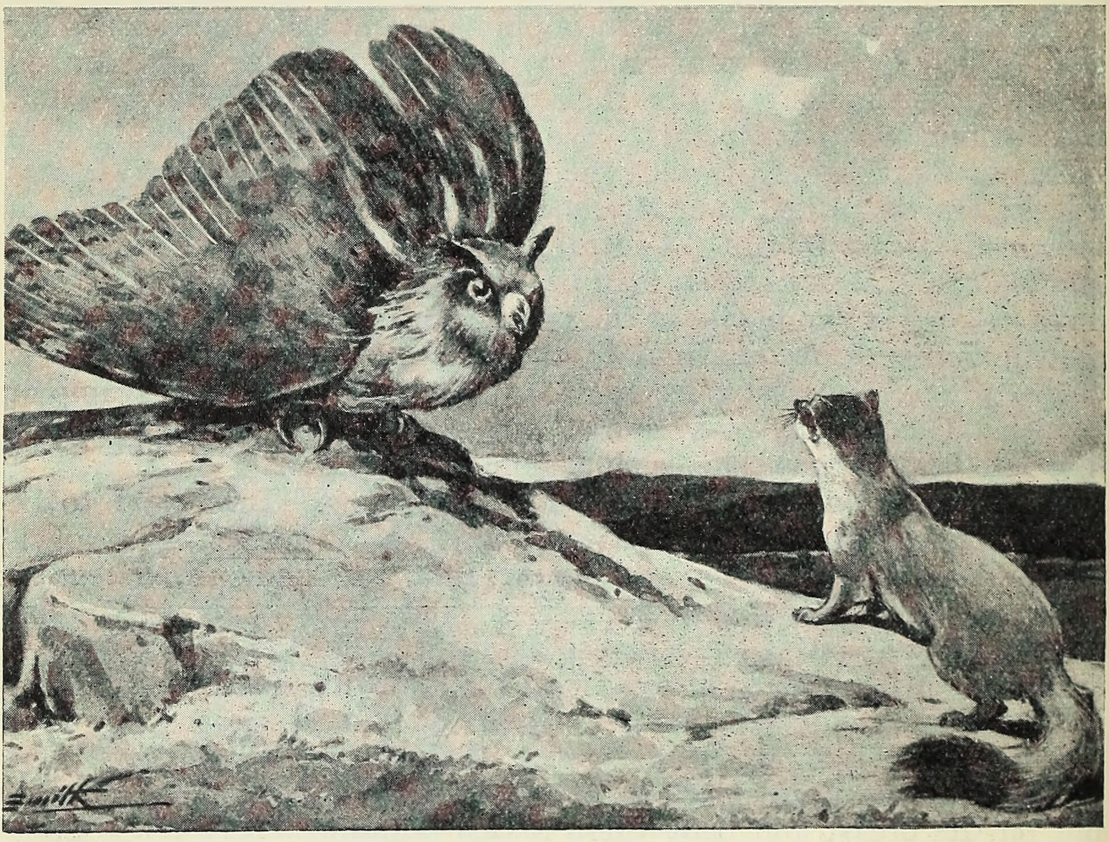


FIG. 259. EAGLE-OWL AND PINE-MARTEN

rather in the way of a bird brooding in a hole in a tree. But they are not there.

It is perhaps a pedantic point, yet it is worth noticing that the quezal's long tail is hardly what it seems to be. For the quezal's true tail-feathers form a short squarish bunch; and the elongated streamers are upper tail-coverts, which remain short in ordinary birds. The same is to be seen, though noticed by few, in a more familiar bird —the peacock. For the peacock's tail is the outcome of an exuberance of the upper tail-coverts, concealing the true tail-feathers, which are relatively commonplace.

The peacock's tail gives us the clue to the quezal's, for there can be no doubt that the yard-long streamers are expressions of masculine

virility, which have given their possessors an advantage in courtship. The cascade of emeralds must enhance the *tout ensemble* of the gorgeous and agile bird. In other words, the male quezals show a remarkable *sex dimorphism*, which has some survival value, inasmuch as the male variants in the direction of longer tail-feathers would tend to be the most successful suitors of the most aesthetic females. The quezals are aristocrats that have bred for beauty.

When we look at quezals, with tail-covert-streamers three feet long, we cannot but recognize a factor in evolution which has not been duly appreciated, though often noticed. We mean organic momentum. A variational tendency in a particular direction may be augmented from generation to generation, from century to century, from millennium to millennium, and thus, even if an additional inch or two means little in preferential mating, the quezal gains its yard-long tail. The only limit is viability, for there is always the risk that the orthogenic momentum may continue to express itself until the exuberance becomes a handicap. This has not happened in the case of the long-tailed male quezals. Their exaggerated tail-plumes, which we regard as biochemical and biophysical expressions of highly sexed masculinity, do not seem to interfere with the solution of the bread-and-butter problem. But the giant Irish deer with its massive antlers crossed the limit of viability, and the species was eliminated because the males were too masculine.

Mr. Osbert Salvin, who watched quezals in Guatemala nearly seventy years ago, tells us that the long tail-feathers of the male ' never seem to be in his way '; and we are glad to be assured afresh that beauty may be exuberant without interfering with bread and butter.

CHAPTER XXI

MAMMALS

Three chief divisions of Mammals—Characteristics of Mammals—Milk—Hair—Horns—Teeth—Habitats—Movements—Illustrations from various orders of Mammals.

The highest animals are the Birds and the Mammals, and they are on such different lines that comparison is difficult. As Man belongs, from the Natural History point of view, to the class of Mammals, we *must* rank this class highest; and, apart from our belonging to the class, it must be granted that most Mammals are superior to Birds in their brains and in the partnership before birth between the mother and her offspring. There are two or three very old-fashioned mammals that lay eggs, as birds and most reptiles do, but all other mammals are **viviparous,** which means that what is liberated from the mother is not an egg, but a fully formed young one. But 'fully formed' does not, of course, mean that the development is finished. In many cases, especially among the pouched mammals, like the kangaroo, the newly born young one is very imperfect. It has a long way to go after birth.

It is interesting to notice that the highest places in the animal kingdom must be given to two classes in which parental care reaches a climax. Most birds build nests, brood on the eggs in patience, and are for a long time occupied in feeding, sheltering, defending, and teaching their offspring. Most mammalian mothers carry their young ones for a long time before birth—eleven months in a mare, only about a fortnight in an opossum. During this time there is a complicated internal 'give-and-take' between the mother and the unborn offspring; and after birth there is the suckling, the sheltering, the defending, and in many cases the education of the young. Armour and weapons are of great importance in many animals, but parental care and affection must also count for much. We think rightly of the value of the eagle's beak and talons, but we must also think of the devotion of both parents to the eaglets in the eyrie. We think rightly of the value of the otter's teeth and claws, but we must also do justice to its almost unsurpassed maternal care shown in nursing, feeding, and training the offspring. Then we shall understand better why Linnaeus called the furred, milk-giving quadrupeds *Mammalia*, for the word refers to the **mamma** or teat by which the young one

sucks the mother's milk. If we try to define Mammals very briefly, we may say that they are usually furred, toothed, warm-blooded, viviparous quadrupeds, and that the mothers always produce milk for the young.

THREE CHIEF DIVISIONS OF MAMMALS.—There are three levels of mammals—first, the egg-laying (or **oviparous**) duckmole and spiny ant-eaters (*Monotremata*), which are in many ways very old-fashioned; second, the *Marsupialia*, like kangaroos, in most of which the mother has an outside pocket of skin in which, after birth, the young ones are carried, sheltered, and nourished; third, all the others, a motley crowd, such as carnivores, hoofed animals, and monkeys, in which the internal partnership between the unborn young and the mother is longer and closer than in marsupials. The organ that links the unborn offspring to the mother is called the **placenta.** It is partly made of the wall of the mother's womb (where the embryo takes form) and partly of two '**birth-robes**' or **foetal membranes** (q.v.) which develop around the embryo. One of these membranes is the protective **amnion,** which forms a dome of fluid round the delicate embryo. The other is called the **allantois,** through which there is exchange of materials between mother and offspring. No solid particle passes from the one to the other, but there is an exchange of fluids and gases between the two sets of blood-vessels. The mother contributes dissolved nutritive substances, oxygen, and '**chemical messengers**' (see HORMONES). The offspring gives back dissolved waste-products and carbon dioxide—a poor return for the food and oxygen it receives, but it also contributes 'chemical messengers' which are useful to the mother. The placenta (sometimes called the '**after-birth**') is a very complicated structure, and far beyond description here, but it is important to understand that the life of the young one before it is born depends on the give-and-take that goes on between it and its mother's womb. The period required for the development before birth varies greatly in different mammals;

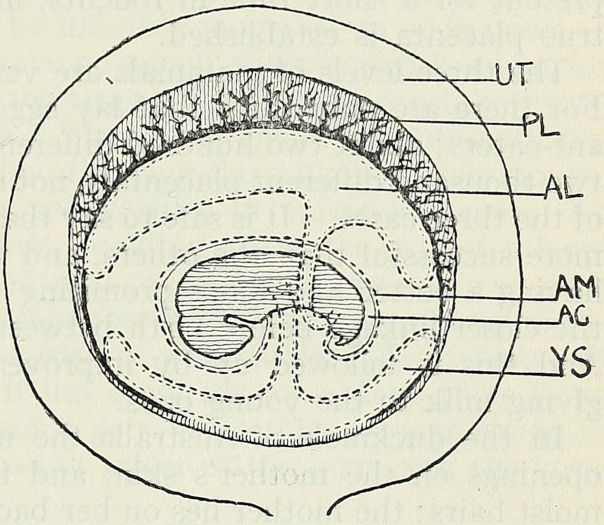


FIG. 260. DIAGRAM OF FOETAL MEMBRANES IN RABBIT.—In part after Bonnet

UT, wall of uterus; PL, embryonic part of placenta, in close union with uterine wall; AL, allantois; AM, amnion; AC, amniotic cavity; YS, yolk-sac.

it lasts for thirteen months in the elephant, eleven in the mare, nine in the human species, but it is much shorter in lower mammals, e.g. three weeks to two months in the rodents or gnawers, like rats and mice. In an opossum it lasts for less than a fortnight, and the young one is peculiarly helpless when it is born. It should be noted that only one of the marsupials (*Perameles*) has what is called a true placenta. The others have a sort of makeshift linkage between the unborn offspring and the mother—a **yolk-sac placenta,** such as is present for a short time in rodents, insectivores, and bats before the true placenta is established.

The three levels of mammals are very unequal as regards numbers. For there are only three that lay eggs—the duckmole and the spiny ant-eaters; about two hundred different kinds of marsupials; and over two thousand different placentals, not counting the fossil forms in any of the three cases. It is safe to say that the placentals have been much more successful than the others, and while this is partly due to their having a better and more promising type of brain, it is also due to the closer linkage before birth between the mother and the offspring. And this is followed up by improvements in the arrangements for giving milk to the young ones.

In the duckmole of Australia the milk oozes out by many minute openings on the mother's skin, and the young ones simply lick the moist hairs; the mother lies on her back, and the young mount on her ventral surface. In the spiny ant-eater the milk comes from the wall of a small skin pocket, like a watch pocket, in which the egg hatches. The milk of the spiny ant-eater is different in composition from ordinary mammal's milk [1]; we do not know anything about the duckmole's.

In marsupials there are teats or mammae, situated inside the skin pocket or **marsupium,** which is formed except in some opossums. The formation of teats is a great improvement, but the young one is born so helpless that it cannot even suck. Yet it manages in most cases to creep into the marsupium unaided. The mother may adjust things so that a teat is pressed into the young one's mouth, which closes on it automatically. By special muscles the mother then forces the milk into her offspring's mouth, for, as we have said, the sucking power is not yet developed. As the teat swells a little in the baby's mouth, there is less chance of its slipping out. But why does the milk not ' go down the wrong way '? The answer is that the opening to the windpipe is shunted forward into the mouth to meet the back opening of the nose-passage, so that air can pass down to the lungs from the outer nostrils, but no milk can pass except along the proper channel, namely, down the

[1] Since it is formed from modified *sweat* glands, not from modified *sebaceous* glands as in placental mammals.

gullet. Using the technical words, we say that the **glottis** is shunted forwards to meet the **posterior nares.** If it were not for this arrangement the young marsupial would be apt to drown in its mother's milk. It is always wise to look the facts in the face, and here we may notice that while most of the arrangements in living creatures work extraordinarily well, they are not always *as yet* perfectly adjusted. No doubt they are in process of evolution. The example that we would give here is that the marsupial mother sometimes brings forth more young ones than there are teats for, more indeed than the pouch can hold. Thus there is bound to be infantile mortality in such cases.

In the other mammals, that have no pouch, there is usually a teat for each young one, and if there is too large a family they can take turns, as we may see among baby pigs. The young ones suck automatically or reflexly, so there is no question of forcing the milk into their mouth, but there are some interesting peculiarities in particular cases, like that which allows the baby whale, suckling in the sea, to get a large mouthful at a time. A foal in natural conditions has to move on with its mother soon after it is born, therefore it gets numerous *small* meals of milk. Contrast with this the case of wild cattle. The young calf is hidden in a thicket, and as it lies quiet for some days there is no objection to big meals, and these it gets. We thus see a meaning in the comparatively small milk-bag or **udder** of the mare and the large one of the cow.

CHARACTERISTICS OF MAMMALS.—(1) With few exceptions mammals are quadrupeds. Only in the whales, dolphins, and their relatives (*Cetacea*) and in the sea-cows (*Sirenia*) is there a suppression of the hind-legs, connected, of course, with the fact that these mammals live in water.

(2) In most cases one can distinguish four regions on a mammal—the head, the neck, the trunk, and the tail. But in a few cases, like whales, the neck is not distinguishable from the outside, and in some other cases, like seals, it is not very noticeable. Similarly the tail may be very short, as in rabbits and bears, or practically absent, as in tree-sloths and apes. In aquatic forms it is flattened dorso-ventrally, as in *Cetacea*, *Sirenia*, and the beaver.

(3) Most mammals have a coat of **hair,** and there is no mammal that does not show something in the way of hairs. But in the whale they may be restricted to a few about the lips; and they are relatively scanty in the sea-cow, hippopotamus, rhinoceros, and modern elephant.

(4) The skin is rich in **glands** (cf. p. 664): (*a*) those that get rid of sweat (*sudorific glands*), and (*b*) those that secrete an oily material that keeps the hair sleek (*sebaceous glands*). There are also, as we have seen, (*c*) the *milk-glands*. Sometimes there are special *skin-glands*, which produce a scent of use in various ways, e.g. in enabling those of

the same kind to recognize one another, or in driving away an intruder, as in the case of skunks. Later on, as an illustration, we shall discuss the weasel's scent (p. 722).

(5) Mammals stand alone in having a muscular sheet—the **midriff** or **diaphragm**—separating the chest-cavity, containing the heart and lungs, from the abdominal cavity, containing stomach, intestine, and liver, and other viscera. The diaphragm is of great importance in breathing, for when it is lowered the cavity of the chest is enlarged and the filling of the lungs with air is helped. When it is raised again the opposite happens.

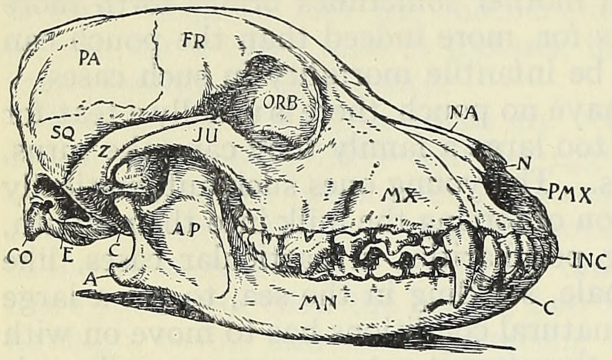


Fig. 261. Skull of Dog

PA, parietal; FR, frontal; ORB, orbit of eye; NA, nasal; N, nostril; PMX, premaxilla; INC, incisor tooth; C, canine tooth; MX, maxilla; JU, jugal; Z, zygomatic portion of squamosal; SQ, squamosal; CO, occipital condyle; E, external opening to ear; C, articulating condyle of lower jaw; A, angle of jaw; AP, process for attachment of muscles; MN, mandible.

(6) There are many peculiarities in the mammal's skeleton, but we must confine our attention to a few. On the vertebrae (except in *Monotremata* and sea-cows) and on the long bones there are special caps of bone (**epiphyses**) which arise from bone-making centres separate from those that form the main part of the bone in question. As long as the bones are growing quickly these caps are readily separated off with a knife, but when growth stops they become inseparable. The surfaces of the backbone bodies or vertebrae are in most cases flat or gently rounded. With few exceptions there are seven vertebrae in the neck; and it is interesting to notice that the exceedingly long neck of the giraffe and the exceedingly short neck of the whale or porpoise have the same number. We also have seven.

The **skull** works on the first vertebra or **atlas** by two smooth knobs or **condyles**, whereas birds and reptiles have but one. The lower jaw or **mandible** is simply one bone on each side, whereas in birds and many reptiles there are six bones on each side. The lower jaw works on the squamosal bone; in birds and reptiles it works on the quadrate, which has passed into the service of the ear in mammals. There is a complete bony palate on the roof of the mouth, whereas there are many gaps between the bones of this region in birds. With few exceptions there are teeth, fixed in sockets, and usually in two sets—a short-lived 'milk set' and a permanent set. Outside of mammals, the only animals with teeth in sockets are the crocodiles and their relatives.

Except in *Monotremata* the coracoid bone is reduced to a mere process of the shoulder-blade or scapula, whereas in birds and such reptiles as lizards it is a strong bone reaching the breastbone. It is interesting that this should also be the case in the duckmole and spiny ant-eater. Another skeletal peculiarity is in the ankle-joint, which is quite different from that of birds and reptiles. If we move our ankle-joint and watch carefully, and then look at a skeleton, we may convince ourselves that the tibia (the stronger of the two long bones below the knee) works against one of the upper-ankle bones called the astragalus. This is called a *cruro-tarsal* ankle-joint. But when a reptile moves its ankle-joint the upper row of ankle-bones moves on the lower row of ankle-bones—an *inter-tarsal* ankle-joint (see BIRD'S ANKLE).

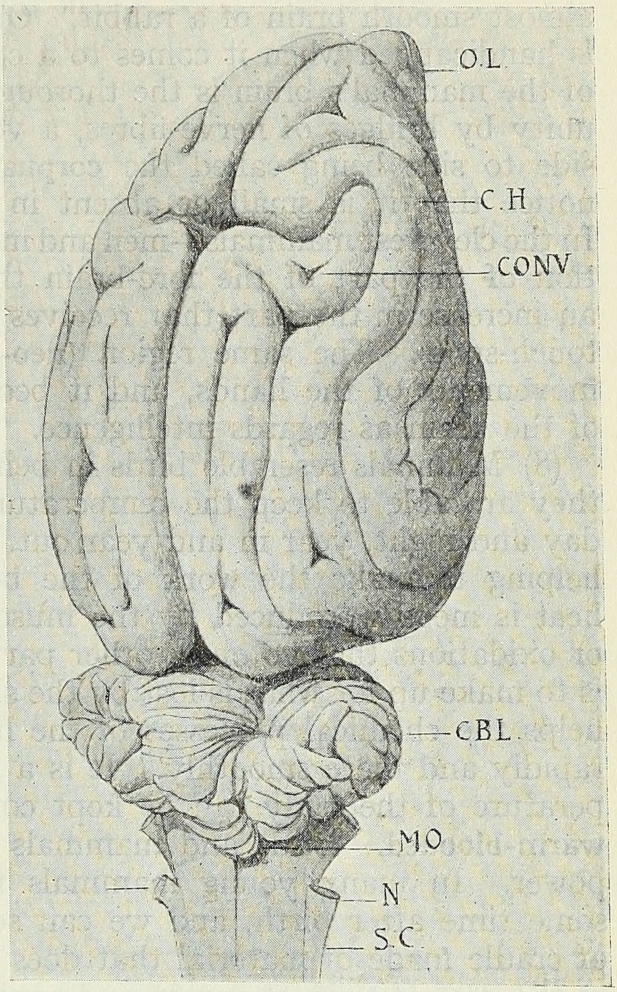


FIG. 262. BRAIN OF DOG

OL, olfactory lobes; CH, cerebral hemispheres; CONV, convolutions; CBL, cerebellum; MO, medulla oblongata; N, nerve; SC, spinal cord.

(7) The **brain** of mammals has made a great advance compared with that of bird and reptile. Two parts have become very large: (*a*) the fore-brain (**cerebral hemispheres**), the seat of intelligence, and (*b*) the hind-brain (**cerebellum**), which has a great deal to do with the control of locomotion. These two parts hide the other three regions of the brain (namely, **optic thalami, optic lobes,** and **medulla**); and in apes the fore-brain is so large in proportion that it hides all the rest of the brain. In clever mammals, like dogs and horses, the outer part (or **cortex**) of the fore-brain grows greatly, and out of proportion to the skull that shelters it, so it becomes convoluted like a crumpled handkerchief. It is covered with ridges and valleys, and it would have a large surface if it were spread out. Most dull-witted mammals have few cerebral convolutions or almost none; their brains

are not wrinkled with thought! Yet there are some small mammals that are clever enough, though their fore-brains are very smooth. This probably means that the surface of the fore-brain in such cases is really large when compared with the size of the creature—large enough to allow of cleverness without convolutions. It is very instructive to compare the richly convoluted brain of a fox with the almost smooth brain of a rabbit. One sees how seriously the rabbit is handicapped when it comes to a contest of wits. Another feature of the mammal's brain is the thorough way in which it is bound into unity by bridges of nerve-fibres, a very important cross-bridge from side to side being called the **corpus callosum.** It is interesting to notice that it is small or absent in *Monotremata* and *Marsupialia.* In the cleverest mammals—men and monkeys—there is a marked reduction of the part of the fore-brain that receives smell-messages and an increase in the part that receives messages from eye and ear and touch-spots. The same region (**neo-pallium**) superintends the finer movements of the hands, and it becomes the most important part of the brain as regards intelligence.

(8) Mammals resemble birds in being **warm-blooded,** that is to say, they are able to keep the temperature of the body almost constant, day and night, year in and year out. This is of great importance in helping to make the work of the body go smoothly. The **animal heat** is mostly produced by the muscles, and partly by combustions or oxidations that go on in other parts. The use of the animal heat is to make up for what is lost by the skin and in breathing, and it also helps the chemical processes of the living laboratory to go on more rapidly and more smoothly. It is a great advantage when the temperature of the body can be kept constant, and this is called being **warm-blooded.** Birds and mammals are the only animals with this power. In many young mammals it is not in working order for some time after birth, and we can see the importance of some sort of cradle made of material that does not readily let the heat out, as in the nest of harvest-mouse and squirrel. Moreover, there are some mammals that are not more than imperfectly warm-blooded, and this is the case with the winter sleepers (see HIBERNATION). The temperature of the blood is high (about 39° C. or 98·4° F. in man), which means that there are a great many chemical changes going on very rapidly and that much of the warmth is being retained; but only a few mammals are as hot-blooded as birds. Bats and cattle are among the hottest. The red blood corpuscles are circular disks, except in the camel family, where they are elliptical. The disks are slightly bi-concave, somewhat like two shallow saucers placed back to back. A blood corpuscle is a cell, that is to say, a unit corpuscle of living matter; and a cell should have a nucleus. But the red blood corpuscles of

mammals show no nucleus after they are fully formed. The nucleus has probably taken the form of fine nuclear dust within the cell. As in birds, the heart is four-chambered.

(9) The expansible **lungs** hang freely in the cavity of the chest, wrapped round in a membrane called the pleural membrane—a different arrangement from that in birds, where the lungs are inexpansible and bound firmly to the ribs. The air that is taken in by the nostrils passes down the windpipe to the bronchial tubes, which fork and fork again to form each lung. This, again, is very different from the irregular 'tree-like' branching of the bronchial tubes in birds. There are no air-sacs in mammals. And whereas the seat of the voice in birds is in an enlargement (the song-box or syrinx) at the *foot* of the windpipe, its seat in mammals is in the **larynx** at the *top* of the windpipe. It is there that the vocal cords are stretched—vibrating and producing sound as the air passes over them, whether in the dog's bark, or the cat's mew, or the monkey's chatter. In mammals, breathing in (inspiration) is the active process and breathing out (expiration) is passive—just the opposite of what it is in birds.

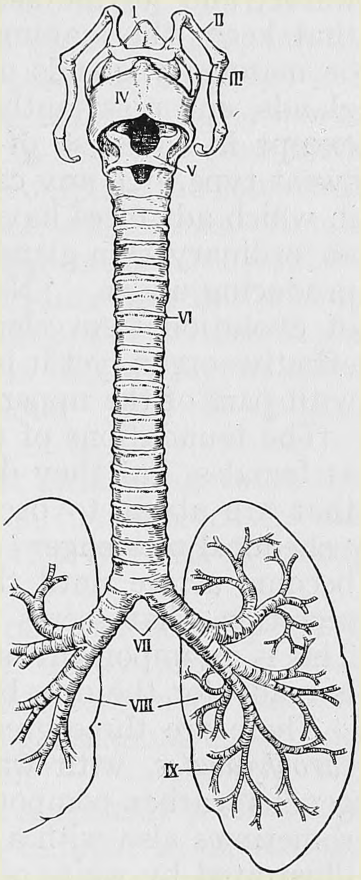


FIG. 263. WINDPIPE AND LUNGS OF MONKEY

I–V, cartilaginous and bony structure of larynx; VI, windpipe or trachea; VII, bronchial tubes (bronchi); VIII, lungs; IX, small branch of bronchus.

(10) In the primitive oviparous *Monotremata* (duckmole and spiny ant-eater) the ova have abundant yolk, are relatively large, and undergo partial segmentation. In other mammals the ova are small and yolkless, and show total equal segmentation. The *Marsupialia* bring forth their young in a very imperfect condition, unable even to suck, and there is no true placenta except in the bandicoot (*Perameles*). In all other mammals there is a true placenta, which establishes a prolonged ante-natal partnership between the unborn young and the mother.

MILK.—The fluid food that all mammal-mothers give to their offspring is a perfect food, since it contains all that is necessary for growth and development. It is the secretion of the **mammary gland**; that is to say, the living units of the gland make milk at the expense of their living matter. The gland consists of a large number of branched tubes with openings on the nipple or teat. In some cases, as in cud-chewing mammals, the skin is continued beyond the ends

of the glandular tubes so that there is a single aperture through which the milk is sucked.

As we have already seen, the skin of mammals is typically very rich in glands. These are of two main kinds: (*a*) the **sweat-glands** (sudorific), which are active in perspiration and get rid of a great deal of water; and (*b*) the **sebaceous glands,** that secrete an oily substance that keeps the mammal's hair in good order. Now the milk-glands or mammary glands are derived from the more commonplace skin-glands, and most authorities say that they are nearest the oily type, except in the case of the *Monotremata*, where they are nearer the sweat type. In any case there is an example here of one of the ways in which advances have been made. Out of an old structure, such as an ordinary skin-gland, a new acquisition appears, such as a milk-producing udder. 'New lamps from old': this is one of the methods of evolution. An elephant's trunk is a very strange and a very effective organ, yet it is nothing more than a very long nose combined with part of the upper lip.

The foundations of the milk-glands are laid down in males as well as females, but they do not usually become active except in females that are about to become mothers. Here is another example of a **'chemical messenger'** or **hormone** (q.v.), for the milk-gland does not become active until the blood brings to it a special trigger-pulling secretion, that seems to be produced by the womb of the mother. This is an important fitness or adaptation, for it makes sure that milk is ready for the new-born offspring.

There are three great kinds of food—*proteins*, *fats* (and *oils*), and *carbohydrates*, with water and salts thrown in. **Proteins** are nitrogenous carbon-compounds (CHON), usually with a little sulphur, sometimes also with a little phosphorus and/or iodine. They may be illustrated by white of egg (egg-albumin), casein from cheese, vitellin from yolk of egg, gelatin from calf's foot, and gluten from wheat. They form an essential part of living matter.

Fats and oils contain carbon, hydrogen, and oxygen, and may be illustrated by the oil in the cod's liver and the fruit of the olive, by suet from the ox and lard from the pig, and by the lecithin of yolk of egg (though lecithin is not a *typical* fat).

Carbohydrates are also compounds of carbon, hydrogen, and oxygen, the two last almost always occurring in the proportions in which they occur in water (H_2O). They include sugars, starch, and cellulose.

To sum up:

Food { PROTEINS, e.g. albumin.
FATS, e.g. mutton-fat, lard.
CARBOHYDRATES, e.g. sugar, starch.
WATER AND SALTS.

Now the most important fact about milk is that it contains all the essentials. Thus cow's milk contains 3–4 per cent of protein, 4 of fats, 4·4 of sugar, 0·6 of salts, and the rest water. The composition of milk differs considerably in different mammals, and it is sometimes possible to connect this with peculiarities in the animal's mode of life. Thus the young reindeer in a cold climate requires a lot of fat, and the milk has 17·2 per cent. The young rabbit has to grow quickly, for the mother will not suckle it long and it is dangerous to be helpless; so it gets much more nutritious milk than the human baby that grows more slowly. The young rabbit doubles its weight in six days after birth, while the human baby requires 180 days to accomplish the same feat. The baby dolphin is born and suckled in the sea, which must often be very cold. It is interesting, therefore, to find that its mother's milk has actually 43·8 per cent of fat, and this helps to produce heat in the body. The fattiness of the dolphin's milk fits in very well, but we should also think of the fact in another way. The milk is the product of gland-cells, that get their raw materials from the blood. But the dolphin, like all its relatives, goes in for making a lot of blubber, which is a buoyant and heat-retaining deposit of fat. It is natural, then, that the fat-producing tendency should show itself in the digested fat that the blood distributes. And it is from the blood that the milk-producing gland-cells get their raw materials.

It is not too much to say that the success of mammals depends in no small measure on milk. Milk is a very handy form of food, available whenever the mother is get-at-able; it is very easily digested; it trains the young food-canal until the young mammal is stronger, and able to tackle such foods as flesh and grass.

But behind all that is the fact that milk is a singularly perfect food. First, it contains *proteins*, such as the casein familiar in cheese, and proteins are the only kinds of food that supply the materials necessary for building up and sustaining the living body. Moreover, the milk-proteins are the very best that a young mammal can possibly get. If it is given wheat-protein, for instance, only 25 per cent can be utilized for growing; if it gets its natural milk-proteins, then it can use 63 parts per cent for growing. Surplus protein material can hardly be said to be storable. Second, there is *milk-sugar*, which supplies energy for the muscles and heat for the body, and if there is any surplus it can be stored as animal starch or as fat. Third, there is the *fat* of the milk, familiar in butter, which also supplies energy to the muscles and heat to the body. It is easily stored beneath the skin and elsewhere. Fourth, the *salts* in the milk help in bone-making, and also in keeping up a proper balance of salts in the blood and other fluids of the body. Fifth, milk contains substances called **vitamins**, which are indispensable to health. We

see, then, that milk is a perfect food. Some tribes live almost entirely on milk.

It must be admitted, however, that there are limits to the ' perfection ' of milk as a food, especially that there is nothing to chew, and that milk is a good culture-fluid for various kinds of microbes, which are sometimes deadly. If we give a dog all the kinds of food that are theoretically necessary, but all in liquid form, the dog will die. The dog requires something to chew and enough solid stuff to keep the muscles of the food-canal in good tone. So, if we give our dog protein-food in the form of raw white of egg, carbohydrate food in the form of syrup, and fatty food in the form of oil, and if we add water, salts in solution, and accessory foodstuffs or vitamins, we are giving the creature all that its living matter theoretically requires for sustenance, and yet sooner or later we kill our dog. Yet we know that in its early days the puppy flourished on its mother's milk and doubled its weight in the first nine days. The milk diet is almost perfect for early growth and development, but it does not work well when the strenuous business of life begins and high explosives, so to speak, are required.

The question arises, how such a perfect food as milk has come into existence; and the answer must be that it is the long result of time. Mammals have a monopoly of milk-giving, but we know that the milk-glands are specializations of the more ordinary skin-glands, like the sebaceous glands that keep the fur sleek and the sweat-glands that have mainly to do with regulating the temperature of the body. It is very interesting to go back as near the beginning of mammals as we can go, to the egg-laying monotremes of Australia, Tasmania, and New Guinea. In the duckmole, as we have seen, the milk oozes out by numerous pores on a patch of the mother's skin, and the young one licks this. There is nothing to suck.

In the spiny ant-eater the openings of the milk-glands are enclosed within a temporary pocket where the egg is placed by the mother and where it hatches. In this case the ' milk ' has been studied, and it is interesting to find that while it is very rich in proteins, it has little or no sugar, and it has no phosphorus salts. In other words, it is very different from ordinary milk, and it gives us an indication of a secretion that came before milk and that was not up to the level of milk. Those mammals succeeded whose milky secretion was effective in supplying the wants of the young ones, and those that did not supply effective milk doomed their race to extinction.

It is interesting that the first milk the new-born mammal gets is much richer than the ordinary milk; and this is also as it should be. We must not think of milk as perfect from the first; it is, like everything else, the outcome of changing and sifting, trying and testing.

Just as man has reared breeds of poultry that lay throughout a great

part of the year and produce a number of eggs that would surprise the ancestral jungle fowl from which all our poultry have sprung, so he has reared cows that give large quantities of milk throughout long periods, after a fashion unknown in Wild Nature. A cow will not continue giving milk unless it periodically bears a calf, but the normal period has been greatly lengthened out. In other words, the cow's prolonged lactation is 'unnatural,' and the outcome of man's selective breeding. It depends on an inborn or constitutional quality, but it is modifiable by nutritive and environmental conditions. The fluctuations in the yield have been the subject of much study, and they require it.

But besides the fluctuations in yield there are fluctuations in the composition of the milk; and this is a matter of great importance. It has been proved up to the hilt that the young children of Britain are not at present obtaining the quantity of milk that they require, and it is all the more important that its *quality* should be good. The value of cow's milk for young children depends on its having the proper proportions of proteins, sugar, fats, and other constituents. So, human nature being what it is, there have arisen legal standards, deviations from which are punishable. Thus saleable milk must contain definite percentages of fats and of other solids besides fats.

It is possible, however, to push somewhat theoretical considerations too far, with the result that a dealer in milk may be made an offender in spite of his thoroughly honest intentions. Milk is a variable secretion, changing with time of milking, with the age of the cow, with the time of year, with the treatment of the commodity, and so on. In bulked milk from large herds the variations tend to cancel one another, but it may be quite otherwise in a small herd.

HAIR.—Mammals are the only animals with hair, and it is so distinctive that it deserves a little article to itself. A little papilla of the outer skin or epidermis grows inwards and is surrounded by a moat or **follicle,** into which a sebaceous gland or more than one may open. The ingrowing papilla of epidermis is met at the base of the moat-like follicle by a projection of the under-skin or dermis, containing capillaries. This projection feeds the growing hair.

When we hold a hair against a strong light we may be able to distinguish a spongy central part and a denser rind or cortex. The outer surface is often rough, as may be seen in bats; and in the Cape golden mole it is covered with very fine lines so that it exhibits **iridescence,** i.e. it shows changeful colouring according as the light strikes it. It has a dark pigment, but the iridescence illustrates what is called physical coloration. Especially on its upper surface, the fur of this old-fashioned insectivore displays 'a brilliant metallic lustre, varying from golden bronze to green and violet of different shades.'

The pigment of the hair seems to be much the same throughout the mammals, though the appearance differs considerably among such types as the tawny lion, the black panther, the ruddy fox, the grey mouse. All are included in the general title 'melanins' (see ANIMAL PIGMENTS), which means dark pigments, and many of the differences are due to differences in quantity, not in kind. Melanin also occurs in the skin of some mammals, and it is familiarly abundant in negroes. There is reason to believe that the blackness serves as a screen, protecting the underskin and deeper layers from too intense illumination.

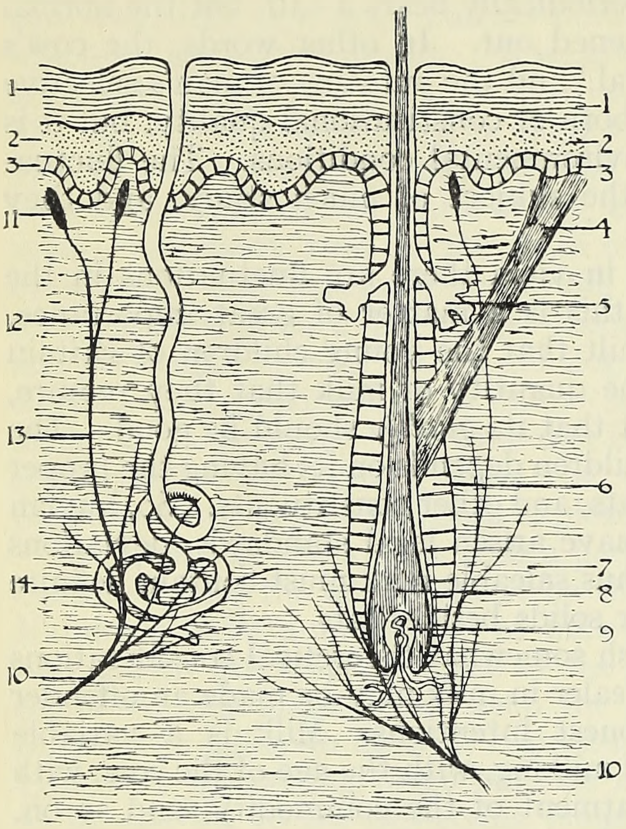


FIG. 264. SECTION THROUGH THE SKIN OF A MAMMAL (DIAGRAMMATIC)

1, stratum corneum, or horny layer; 2, Malpighian layer; 3, actively dividing cells at base of 2; 1, 2, and 3 form the epidermis; 4, erector muscle of the hair; 5, sebaceous or fat-gland; 6, cylinder of horny cells growing down from epidermis into dermis (7) beneath and forming the follicle; 8, hair; 9, vascular papilla at base of hair-follicle; 10, nerve in dermis; 11, nerve papilla; 12, duct of sweat-gland; 13, branch nerve; 14, sweat-gland.

White hair, as in ermine and Arctic fox, is due to the absence or scantiness of pigment and the presence of gas-vacuoles which reflect the light just as in the case of snow crystals and bubbles of foam. When a mammal changes to a white colour at the onset of winter, this is usually due to the replacement of the coloured hairs by a new suit of white ones. This is the case when the brownish-red stoat changes into the ermine—snow-white save for the black tip of the tail. But it does sometimes happen that individual hairs change from brown into white by a bleaching of the melanin and the formation of minute gas-bubbles, or by the disguising of the pigment by a strong development of bubbles. This is sometimes the case in the mountain hare, which changes from brown to white. To the question, how could pigment suddenly disappear from a hair, the answer, given by Metchnikoff, was that wandering amoeboid cells (see AMOEBA) ascend into the hair, engulf granules of pigment, and descend with them into the skin. But this picturesque story

seems to have been a mistake. While there is, strangely enough, a white melanin, the whiteness is almost always due to reflection from the surfaces of bubbles of gas.

As to the use of a white dress in winter, it seems to make the animal more comfortable. That is to say, a warm-blooded animal in very cold surroundings gets on better with white fur than with fur of any other colour, the reason for this being that the loss of the precious animal heat is least when the colour is white. But there may also be some value in having white fur when there is a background of snow. The white hare may escape the hungry eye of the eagle, and the ermine may be helped to steal upon the grouse. In short, the white fur may sometimes be a cloak of invisibility. This view need not be given up though it is not so convincing as was once supposed. There are many difficulties. Thus the more continuous the background of snow, the more does the white hare seek for bare places where it can find food, and on these bare places it is often very conspicuous.

Besides change of colour in the course of the year there is change in the course of life. The flaxen-haired baby becomes a brown-locked boy, and he in turn may become dark, though never black. The appearance of grey hairs, which may be studied in the horse as well as in man, means that in the fresh growth of hair there has been little or no deposition of pigment, but considerable production of gas-bubbles. Sometimes, among men, the change takes place very rapidly in very trying circumstances. Thus General Greely, the Arctic explorer, had dark brown hair which became completely white in the course of some months, probably because of the conditions of semi-starvation and great anxiety. Within a year after the explorer's return to civilization his hair had darkened again, though it never returned entirely to its original colour.

The sudden blanching of Marie Antoinette's hair is believed to be an historical fact, and there are well-authenticated cases of a man's hair turning white in a single night. This is too rapid to be the work of the wandering amoeboid cells which can carry away pigment granules, and it is interesting to find that in a case investigated by the physiologist Landois the colouring matter was found to be still present, but masked by a profuse production of gas-vacuoles both in the core and in the cortex of the hairs.

When we peer into the fur of a wild rabbit, we see that the colouring is very complicated. It looks as if there were many colours subtly mixed together. This is proved by careful experiments, which show that there are about eight factors that make up the colouring. When some of these drop out of the inheritance, the offspring have some new colour, like yellow or black. It is in this way—by a losing of

different factors—that the differently coloured breeds of tame rabbits have arisen. If these are allowed to breed together for several generations, there is a restoration of the original number of factors —the different breeds making good the deficiencies of their neighbours. The result in a year or two will be that all the younger rabbits are like wild ones in their fur. This shows that even the colour of a rabbit is not a simple affair.

An **albino** is an individual animal in which the hereditary factors for producing superficial colour are entirely absent, as in white rats, or white mice, or white rabbits, whose offspring are always white. A true albino may be known by the reddish eyes, for this means that there is no pigment in the iris and thus the colour of the blood in the blood-vessels is seen shining through. It is plainly necessary to distinguish the hereditary absence of pigment (**albinism**) from simple whiteness of colour. For the white ermine, the white Arctic fox, the white mountain hare are not albinos, as their summer forms show. Albinos are freaks or sports that breed true, and though they may occur in Wild Nature, they do not last. The domesticated race of white rats is derived from the common brown rat species, not from the black rat, as is sometimes said.

Before we leave the colouring of the hair we must notice a few peculiar cases. **Piebalds,** e.g. among ponies and cattle, are due to the coarse-grained combination of two different colour-contributions from parents or ancestors. Instead of **blending,** as sometimes happens, they remain apart, and find expression in different parts of the body.

Many mammals are spotted like the leopard or striped like the tiger. In other words, the conditions of pigment-deposition are different in different parts of the skin. Just as we often see lines of colours on a hill-side because different plants grow in different places, according to the presence of streamlets and so forth, so we may try to connect the spots and stripes on the mammal's coat with the course of the blood-vessels and nerves. But it is not easy. The famous racehorse Eclipse had a peculiar spot of colour, and many of his progeny showed the same, even to the sixth generation. Such a trivial thing as a white forelock may reappear for several generations in a human lineage.

It is probable that spots and stripes and other diversities of colour, as well as the general hue, sometimes make a mammal inconspicuous in certain surroundings: as the tiger in the jungle and the hare on the ploughed land. But each case of so-called camouflaging must be carefully scrutinized, since peculiarities of coloration may mean nothing more than idiosyncrasies, i.e. expressions of the animal's particular constitution. It is not necessary to search for a use for everything.

One of the peculiar cases is that of *Notoryctes*, a rare mole-like marsupial of Australia. It is a blind burrowing animal and has an unusual

red colour which seems to disappear from museum specimens. Another peculiarity is the green colour of the shaggy tree-sloths of Central and South America. The colour is due to minute green algae which live on the surface of the rough hair, just as some of their relatives grow on the trunks of trees or on palings in damp weather. Their presence on the hairs may not mean much, but it possibly helps to make the sloth invisible among the foliage.

There are different kinds of hairs and transformations of hairs—the short under-fur of 'sealskin,' the long hair of the horse's tail, the soft wool of sheep that tends to mat together so that the fleece of the Shetland 'murrit' sheep may come off in one piece, the bristles of pigs, the spines of the hedgehog and the porcupine, the delicate eyelashes, the sensitive **vibrissae** on a cat's cheeks or a whale's lips. These sensitive hairs have nerve-endings at their base, and they are often important in touch. They are not necessarily confined to the cheeks and lips, but may occur at other useful places, such as the under-surface of the wrist region, as may be seen in the stoat.

But there are other skin structures that cannot be ranked in the hair series, e.g. the **scales** on the tails of rats and beavers, and the extraordinary horny plates which occur along with hairs on the pangolin (*Manis*). Also notable are the thickened skin-pads or **callosities** on the legs of horses, on the breast of camels, and on the hips of apes. Then there are the horny **nails** or **claws** usually present at the tips of the fingers and toes. They are absent from the flippers of whales and dolphins, where there is, of course, no need for gripping. In bats the thumbs are clawed, but not the fingers, except the second in most of the fruit-eaters. They would be in the way in flight and in folding up the wing. In cattle, sheep, deer, pigs, horses, and other ungulates, the nails are transformed into hoofs, which ensheathe the ends of the fingers and toes. Quite unique is the armour of the armadillo, which can roll up into an unopenable ball, for it consists of an armature of bony plates (or **scutes**) in the under-skin or dermis, and outside these a horny epidermis.

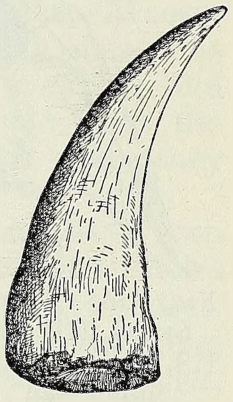


Fig. 265. Horn of Rhinoceros

HORNS.—There are three or four quite different kinds of horns in mammals. (1) The rhinoceros has an unpaired median solid horn or two horns, one behind the other; and each may be compared to a greatly exaggerated wart. (2) The paired horns of cattle, sheep, and antelopes consist of a solid core of bone, growing out from the forehead (frontal bones), and an external sheath of horn much longer than the core. A horn-spoon or any such article is made of the sheath only. (3) The **antlers** of stags begin as short bony stalks

growing out from the frontal bones and carrying the skin with them. This part, known as the pedicle, is permanent. In the second year a short stem, first gristly, then bony, covered with soft skin (the '**velvet**'), grows out from the top of the pedicle. Its covering of skin wears off and, by and by, in a remarkable way the antler is separated off from the top of the stalk and falls to the ground. In the third year the growth begins again, but the second antler has a stem and one branch or '**tine.**' This antler also falls off. In the fourth year there grows the third antler with a stem and two 'tines.' The rule is that a tine is added every year till the stag is full-grown, after which the yearly addition of tines is more irregular. The growth of antlers is one of the most remarkable growths in the animal kingdom. It takes place rapidly; it means an enormous expenditure of material, for a pair of antlers may weigh over seventy pounds; it usually lasts only for a season, after which the beautiful structures fall off; it is confined to the males except in the reindeer, where both sexes have antlers. Perhaps the strangest feature is that antlers do not seem to be of much use, for they are not conspicuously effective as weapons when rival stags fight with one another or when a stag stands at bay against wolves. Perhaps antlers are in the main just exuberant expressions of the vigorous male's constitution. The material for the growth of the soft and sensitive skin or velvet is supplied by blood-vessels in the skin itself, but the growing gristle and bone of the antler is nourished by internal blood-vessels. The dying away of the skin and of the antler is due to an obliteration of the blood-vessels, but this is a rather intricate business. The same is true of what happens to separate off the dead antler. *Why do we not see more antlers lying about?* Perhaps we do not know where to look; but part of the answer is that the deer nibble them, the marks of their teeth being sometimes

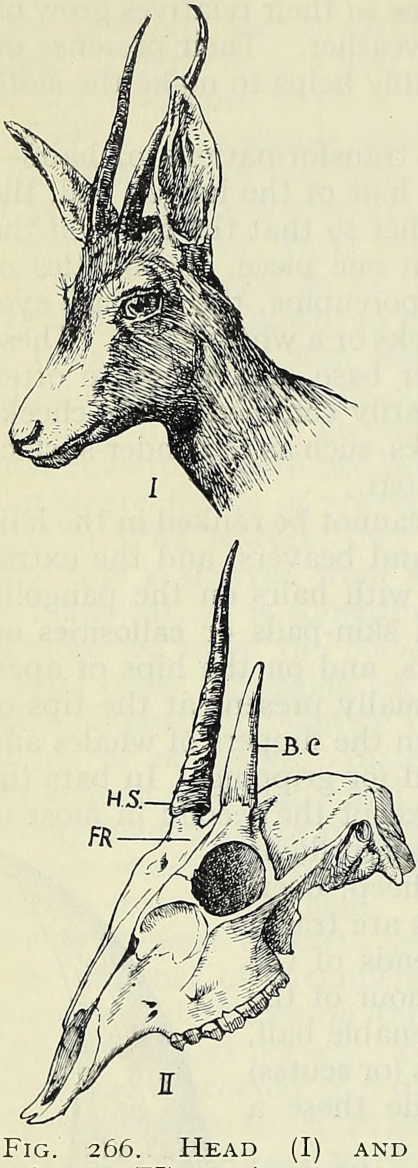


FIG. 266. HEAD (I) AND SKULL (II) OF ANTELOPE
HS, horny sheath; BC, bony column—an outgrowth of the frontal bone (FR).

clearly visible. But this is the least puzzling of the many questions that might be asked about antlers!

In giraffes there are two skin-covered bony horns rising at the junction of the forehead-bones (frontals) with those on the top of the head further back (parietals). In front of the pair there is a median knob; in some cases there are several knobs. In the rare okapi, a West African relative of the giraffe, the male has two short, backward-projecting bony horns situated behind and above the eyes on the frontal bones. The horns of the North American pronghorn (*Antilocapra*) are peculiar in two ways: (1) the horny sheath bears a branch or prong, and (2) the whole of the horny part falls off every year, leaving the bony core.

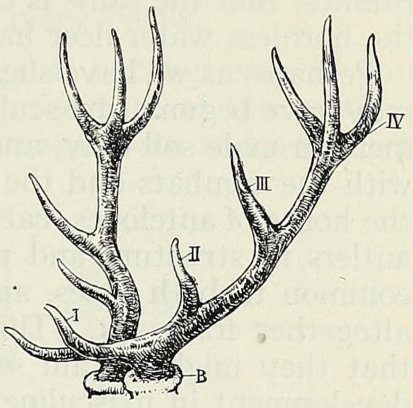


FIG. 267. ANTLERS OF STAG
B, beam; I, brow-tine; II, bez-tine; III, trez-tine or 'royal'; IV, branched 'crown, or 'surroyal.'

ORIGIN OF HORNS AND ANTLERS.—There are two rival theories of the origin of horns and antlers, but it is possible that both are right. According to the one theory, horns and antlers were, to begin with, characters of the species, or genus or type, useful as defensive weapons, or otherwise quite apart from sex. But they afterwards became linked to the male sex, finding their full development only in what we may call male soil. Their presence in males was justified in the course of Nature's sifting because of their utility in contests with rivals, or even as decorations in exciting the sex interest of the females. According to the other theory, horns and antlers were, to begin with, masculine variations, sex-linked, primarily associated with the combats and exhibitions of males, which became secondarily in some cases the common property of both sexes, notably in those forms where they were turned to everyday use.

For the second theory there are many arguments, which have been summed up by Professor J. F. van Bemmelen. In deer the antlers are confined to the males, except (as already mentioned) in the reindeer, where they are exhibited by the females as well. In those antelopes in which both sexes have horns those of the female are usually smaller. The annual shedding of the antlers in deer and their regrowth are apparently connected with the male rut, and the same is said to be true of the North American pronghorn. In many cases the head growths are too cumbrous and exaggerated to be suitable for ordinary defensive purposes; they often show the exuberance, quaint complexity, and variability that are characteristic of secondary sex characters.

It has been suggested, on the other hand, that with a reduction in the development of tusks there was more need for, and more material for, the development of frontal outgrowths. In this connection it is noteworthy that the hornless chevrotains or deerlets have strong canines, that the same is true of the musk-deer, and that the male of the hornless water-deer has also strong canines.

Perhaps, as we have suggested, both theories may be true. Antlers may have begun as masculine variations, capable of attaining development in male soil only, and having their selection value in connection with the combats and the display of the males. On the other hand, the horns of antelopes, cattle, sheep, and goats, so very different from antlers in structure and mode of growth, may have been originally common to both sexes, and justified by some utilitarian value apart altogether from sex. This would not be inconsistent with the fact that they might attain secondarily to a larger or even exaggerated development in masculine soil.

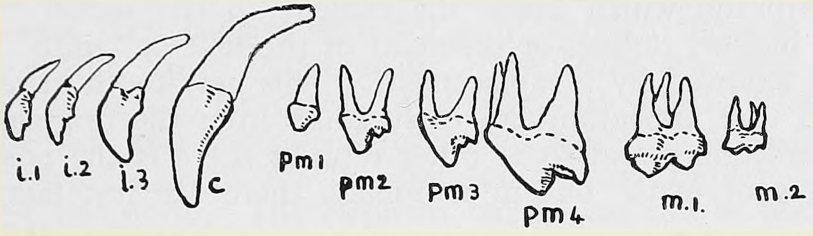
TEETH OF MAMMALS.—Many other animals besides mammals have teeth; they are present in most fishes, amphibians, reptiles, and some extinct birds. But the teeth of mammals, compared with those of other Vertebrates, are on the whole more perfect and show in most cases more division of labour. Thus in the upper jaw it is usually possible to distinguish the front teeth or incisors, the sharp canines (sometimes called 'eye teeth'), and the cheek teeth. The anterior cheek teeth or premolars occur in two sets—'milk teeth' and permanent teeth—as is true of those in front of them. But the teeth further back (the molars) are only once represented as hard teeth. What we call 'wisdom teeth' in man are the last or third molars, and the name refers to the fact that they are late to appear (from the seventeenth to the twenty-fifth year), when their possessors should be acquiring wisdom. In some people they never cut the gum. Thus the four kinds of teeth are incisors, canines, premolars, and molars.

The teeth of mammals develop in the gum or soft tissue covering the jaws—that is to say, the premaxilla and maxilla bones in the upper jaw and the mandible that forms the lower jaw. An insinking from the outer skin of the gum forms a number of 'enamel germs,' and each of these is met from below by an upgrowing papilla of the under-skin or dermis. This papilla forms the ivory of the tooth, and also, as long as growth goes on, an internal pulp with jelly-like tissue, blood-vessels, and nerves. The pulp contributes to the growth of more ivory. The 'enamel germ' forms a hard cap of enamel over the crown of ivory. Round the base of the young tooth a cavity is formed which becomes the socket, and secures firm fixing. The walls of this sac may form around the base of the tooth and up the sides a bone-like tissue, called cement.

To sum up:

A tooth shows
(1) A cap or outer layer of **enamel.**
(2) Ivory or **dentine,** forming the bulk of the whole.
(3) **Internal pulp** as long as growth continues.
(4) Some **cement** outside the ivory below.

From the clean skull of a rat or a squirrel it is often easy to pull out an incisor tooth. A glance shows that the base of the tooth is not narrowed in any way, and, if the skull is still fresh and not dried



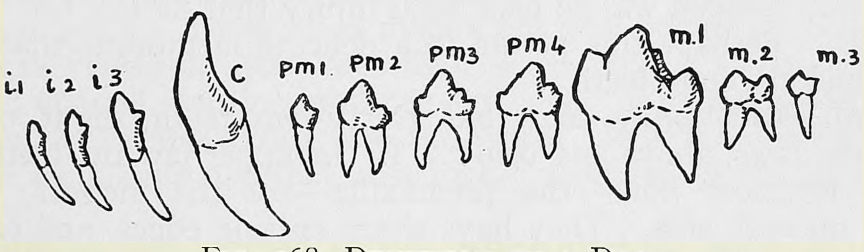


FIG. 268. DENTITION OF A DOG

i 1, 2, 3, first, second , and third incisors; *c*, canine; *pm* 1, 2, 3, 4, first, second, third, and fourth premolars; *m* 1, 2, 3, first, second, and third molars. The faint line indicates the boundary between the projecting part of a tooth and the rooted part embedded in the jaw.

up, the interior contains some of the pulp-tissue. Such a tooth is said to be ' rootless,' with pulp persisting as long as the animal lives. The advantage of this to a gnawing or rodent mammal is plain, for growth can readily continue to make up for what is worn away in gnawing. The other peculiarity of the rodent's incisors is that they are chisel-edged, which makes them well suited for cutting hard things. The making of this chisel-edge becomes very plain when we notice that the enamel is confined to the front of these teeth, or is at most very thin behind. Thus the back of the tooth wears away more rapidly than the harder front surface, and this must result in a chisel. If the squirrel's skull is complete, it will be noticed that the lower incisors work against the posterior surface of the upper incisors. At this place in rabbits and hares there is a hidden pair of diminutive second incisors absent in other rodents.

We see, then, what is meant by a 'rootless' tooth; but most teeth are very different. In the great majority of cases the base is narrowed and drawn out into a **root** or several roots (sometimes called 'fangs'), firmly fixed in the socket. A little hole at the end of a root serves for the entrance of blood-vessels and nerves which enter the pulp-cavity. When growth is complete the last residue of the pulp tends to disappear. A **loose tooth** means that the limit of growth has been reached, that the pulp is used up, that there is an absorbing of the root or roots, and that there has been a breaking down of a dense fibrous membrane which binds the cement to the socket. If the tooth is an incisor, canine, or premolar of the first or 'milk' set, its loss will be followed by a replacement. This new tooth arises from a small bud that appears at an early stage from the original tooth germ. In crocodiles and some other reptiles there is the possibility of many sets of teeth, but in mammals there are not more than two sets.

We often hear the phrase, 'the skin of the teeth,' in reference, for instance, to a narrow escape. The suggestion probably is that the person who escaped was so near fatal injury that he lost the 'skin of his teeth.' Perhaps this points to a delicate membrane that covers the enamel in young teeth.

DENTAL FORMULAE.—Man has thirty-two teeth, eight on each side of the jaws, above and below. In the upper jaw the teeth borne by the foremost bone—the premaxilla—are the incisors, two in number on each side. They have sharp cutting edges, and each has but one root. The canine is defined as the tooth immediately behind the junction between the premaxilla and the next bone, the maxilla (see SKULL). The rest of the teeth, like the canines, are borne by the maxilla, namely, the two premolars (or bicuspids) with two points or cusps and often with double roots, and the three molars with four or five points and two or three roots. The lower jaw or mandible is composed of one bone on each side, and its teeth are named according to those that they work against on the upper jaw; and the molars are again distinguished from the premolars by occurring only in one calcified set. All this may be summed up in a 'dental formula':

$$\frac{2\,i,\ 1\,c,\ 2\,pm,\ 3\,m}{2\,i,\ 1\,c,\ 2\,pm,\ 3\,m} = 3^2$$

or, more shortly:

$$\frac{2\ 1\ 2\ 3}{2\ 1\ 2\ 3}$$

The denominator is needed because in many mammals the teeth on the lower jaw differ in number from those in the upper jaw. A few

examples of formulae may be given: opossum, $\frac{5134}{4134}$; pig, $\frac{3143}{3143}$; sheep, $\frac{0033}{3133}$; horse, $\frac{3143}{3143}$; rabbit, $\frac{2033}{1023}$; rat, $\frac{1003}{1003}$; dog, $\frac{3142}{3143}$; hedgehog, $\frac{3133}{2123}$; American monkey, $\frac{2133}{2133}$; Old World monkey, $\frac{2123}{2123}$.

PECULIAR TEETH.—The tusks of the elephant are not canines, as tusks usually are, but incisor teeth, whose roots grow back into the maxillae. They are confined to the upper jaw in modern elephants and they consist of ivory only, though there is a patch of enamel at the tip of young teeth. The tusks are used in fighting, but also in digging for roots. The right one seems to be more used than the left, and becomes shorter and lighter. A single tusk has been known to weigh 188 lb., but the average for left and right is about 75 and 65 lb. The elephant has no canines or premolars, but the molars are so immense that the jaw cannot hold at one time more than two well-developed teeth and part of a third. When these are lost in the course of the elephant's long life, there are three more to take their place. These huge molars are well suited to grind down the coarse vegetable food, and their worn surface shows successive layers of enamel, dentine, and cement. The peculiar pattern is due to the enamel being folded into the ivory. It is interesting to note that the elephant's are the most highly modified of all mammalian teeth.

In dolphins and toothed whales, which feed on fishes and squids, swallowing them whole, the teeth are numerous and all alike—sharp and recurved. They are thus well suited to take a firm grip of the struggling and slippery booty. One might think that these numerous similar teeth represented an old-fashioned simple dentition, but their development suggests that the simplicity has come from previous complexity. It is a new-fashioned uniformity, specially suited for fish-catching. In the whalebone whales, which feed on delicate creatures like the Open-Sea molluscs called ' sea-butterflies,' there are no visible teeth. But it is very interesting to find that there are actually two sets of teeth which never cut the gum, though the milk set goes the length of becoming hard. Here we see the distant past living on in the present, for the whalebone whales must have had toothed ancestors.

The largest and strangest of all teeth is the ' horn ' of the male narwhal (*Monodon monoceros*), an Arctic whale. It is practically the only tooth, though occasionally double; and it is rudimentary in the female. Like the elephant's tusk it is an incisor, but it projects straight out from the front of the head on the left side to a distance almost equal to half the length of the animal, which is about fifteen feet

long when full-grown. In the unborn narwhal there are traces of two other teeth, and there can be little doubt that the animal is descended from a whale with many teeth. The ' horn ' is made of ivory, and though quite straight is beautifully twisted on itself. Its use is very obscure, for while some say that the narwhal uses it to break the ice or to spear a fish like a skate, this seems highly improbable since it is only hinted at in the female. Males have been seen crossing their ' horns ' as if they were fencing, and probably the strange tooth is, like the stag's antlers, an exuberant expression of the masculine constitution. But it is plain that more observations are urgently needed.

It is interesting to notice how different kinds of teeth are suited for different kinds of food. The chisel-edged front teeth of rats and mice, beavers, squirrels, and other rodents, are well adapted for gnawing more or less hard parts of plants. The cheek teeth of hedgehogs, moles, and other insectivores bear several sharp points or ' cusps,' a little like the peaks of mountains, and these are well suited for crunching such animals as insect-grubs, earthworms, and small snails. The cheek teeth of grass-eating animals like sheep, cattle, deer, and antelopes have broad crowns with cross-ridges of enamel, and these are suited for grinding the food into pulp. In a lion's skull the small incisors do not count for much, the strong and sharp canines are quick to kill, the last premolar (called the *carnassial* or *sectorial*) has a special cutting blade well suited for severing a victim's limb or for cutting the muscles and their tendons from off a bone. We see the dog using its ' carnassial ' in stripping the last shred off a bone. The carnassial is also well developed in the cat, as indeed in all *Felidae*.

In regard to **toothless mammals,** a distinction must be made between two kinds. (*a*) There are two families in which there is never any trace of teeth, even before birth, namely, the spiny ant-eaters of Australia and New Guinea, and the bushy-tailed great ant-eaters of South America. (*b*) There are others that show teeth in early stages, but lose them afterwards. Thus the whalebone whales, as we have mentioned, have two sets of teeth that never cut the gum. The pangolins of Africa and India have only rudimentary teeth. The duckmole of Australia has true teeth when it is quite young, but these are lost in about a year, and their place is taken by eight horny plates.

Habitats of Mammals

Most mammals are terrestrial, but unless a creature is small, or agile, or inconspicuous, or in some way formidable, it is not easy for it to live on the surface of the earth. Thus we find among mammals many burrowers, such as moles and prairie-dogs and rabbits. Others

have become arboreal, like squirrels and tree-sloths and monkeys. Some of these have parachutes of skin, and are able to swoop from tree to tree, like the 'flying phalangers' among marsupials, the 'flying squirrels' among rodents, and the 'flying lemur' (*Galeopithecus*), which is related to insectivores. Bats have gone one better, for

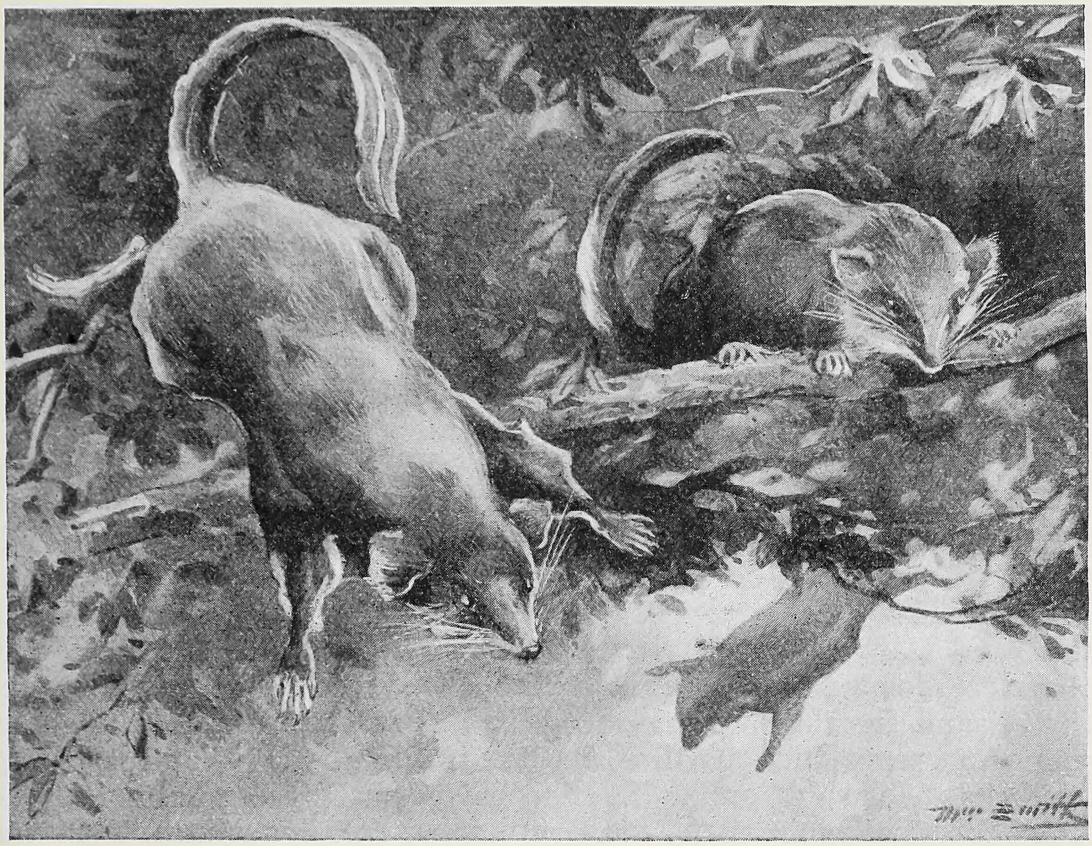


Fig. 269. Flying Phalangers

they have the power of true flight, that is to say, they strike the air with their wings. They can clamber on trees, on the sides of caves, among rafters, and so on, but in their *active* life, mostly in the twilight and darkness, they are genuinely aërial mammals. Let us consider aquatic mammals less summarily, for their change is the most striking.

AQUATIC MAMMALS.—There can be no doubt that mammals evolved from a terrestrial reptilian stock—perhaps from those that are represented by the extinct *Theraspid*—and that the theatre of their evolution was on land, probably in South Africa. Perhaps it was ten million years ago (in Triassic times) that pygmy mammals emerged, and for ages they did not make much headway. Elusive dwarfs hiding from the giant reptiles, they spent most of their time hunting for insects among the branches. They did not give much promise of the

great future that was before them. Millions of years passed until, in the Upper Cretaceous and Early Tertiary times, mammals began to come to their own. There was a marked improvement in brains, and there was an exploration of new haunts—the underworld, the trees, the caves, and the air—and a return to aquatic haunts, some mammals seeking out the fresh waters, others going down to the sea. It is the return from terra firma to water that we wish to consider, with particular reference to the problem of **re-adaptation.** For it is interesting that mammals, which were primarily, and we might almost say painstakingly, adapted to the dry land, should become secondarily adapted to the water.



FIG. 270. DUCKMOLE

The most primitive aquatic mammal is the **duckmole,** or **platypus,** of Australian rivers —a mammal in which there linger many reptilian features, such as the lizard-like pectoral girdle, and the habit of laying eggs. It is a rather squat creature, with a broad bill like a duck's, having a sensitive collar at its base, a flat tail, and many other peculiarities. But our question here is: How is the duckmole adapted to aquatic life? It swims by means of its fore-limbs, and the fingers are webbed as well as clawed. Everything is done to reduce friction; thus, the ear-trumpet is very inconspicuous, and the fur is short and soft. The bill is suited for grubbing in the mud for small animals. As the animal makes long burrows in the banks, it remains less thoroughly aquatic than, let us say, a porpoise, and the adaptations to life in the water are relatively superficial.

Also somewhat primitive are the **sea-cows** (*Sirenia*), an order nowadays represented only by the **dugong** and the **manatee.** They are sluggish vegetarian mammals, with massive, heavy bones and poorly developed brains. The dugongs frequent the Indian Ocean and the Pacific; the manatees live in the mouths of the great rivers that flow into the tropical Atlantic, and one of them goes far inland among the 'Everglades' of Florida. Their fitnesses for aquatic life may be illustrated by the somewhat torpedo-like shape, the flattened tail, the flipper-like fore-limbs, the disappearance of hind-legs, the absence of an ear-trumpet, the closeable nostrils on the top of the snout, the presence of blubber, and the breaking up of some of the arteries into numerous branches—a peculiarity which is said to be useful in prolonged immersion. In short, the sea-cows are bundles of adaptations

to life in the water. Some of the details are very instructive. Thus there is evidence that the dugong took to the water before the manatee, for the tail has flukes like a whale's, whereas the manatee's is simply rounded; the fore-arm of the flipper is almost completely enclosed within the body, whereas it is freely exposed in the manatee. Moreover, the nails are absent in the dugong, while in the manatee they linger in a rather rudimentary condition, except in one species, where they have vanished. These are straws which show how the wind has blown. Again, to take one other instance, the sea-cows have only sparse hair on their thick, tough skin, but the unborn manatee has a thick coat of rudimentary fur.

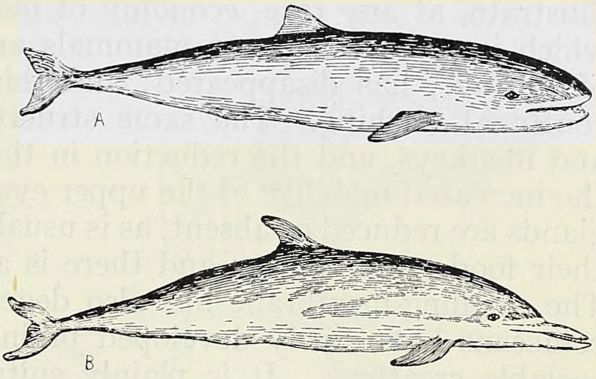


FIG. 271. PORPOISE (A) AND DOLPHIN (B)

The climax of aquatic adaptation is seen in the whales and dolphins and other *Cetacea*. They have many primitive features, but they are at the same time highly specialized for marine life. It is unfortunate that their pedigree is quite obscure, and even of their affinities with other orders of mammals little can be said. They do not seem to be at all near the sea-cows. As every one knows, they include the giants of to-day, for even an elephant could be easily contained within the contour of a sulphur-bottom whale eighty-seven feet long. This gigantic size is, of course, correlated with the fact that in the water they have not to support their own weight.

What are the **fitnesses** (adaptations) of a whale? The torpedo-like shape is well suited for cleaving the water, and the flukes of the tail form a powerful propeller. The skin is frictionless and almost naked; the few hairs that usually remain about the lips are exquisitely tactile. Cetaceans seem to produce a large quantity of animal heat, as we should expect in creatures so muscular, and this is well conserved by the layer of non-conducting **blubber.** The blubber also increases the buoyancy of the animal, and, when we notice that it is simply an exaggeration of the layer of fat found underneath the skin of most mammals, we get a glimpse of Nature's way of making an apparently new thing out of something that is very old. The fore-limbs have been transformed into paddle-like flippers, which are moved *en bloc* and are mainly used for balancing. Of the hind-limbs and hip-girdle there are only vestiges left, and these deeply buried. In adaptation to deep diving the neck has been shortened down and the vertebrae soldered together. The bones show a remarkable

sponginess, which makes for buoyancy. Then there is the reduction of friction, as illustrated, for instance, by the absence of any ear-trumpet.

To suit the driving out and the taking in of air on the surface of the sea, the automatically closing nostrils or blow-holes (reduced to one in the adult toothed whales) are far back on the top of the head. The huge chest capacity, the spacious lungs, and the remarkable networks of blood-vessels will help in the prolonged immersion. Besides positive fitnesses there are interesting negative features which illustrate, at any rate, economy of material. Thus the third eyelid, which is present in most mammals and used for cleaning the front of the eye, has disappeared; and this may be correlated with the continual washing. The same structure is a mere vestige in man and monkeys, and the reduction in this case may be correlated with the increased mobility of the upper eyelid. In cetaceans the salivary glands are reduced or absent, as is usual in aquatic animals that devour their food under water; and there is also a reduction of skin-glands. The smelling-membrane has also degenerated. Unlike the sea-cows, cetaceans have finely developed brains, and in most cases they are sociable creatures. It is plainly suitable that there should usually be only one young one at a birth, that it should be very precocious, and that there should be special milk-reservoirs for giving it a big drink in a short time.

We have taken three very different examples—the duckmole, the sea-cows, and the cetaceans—from which we may learn much. But it is of value to picture vividly the evolution series which is so plain among carnivores. We may begin with an animal like the stoat that occasionally jumps into the water and swims well. The next step may be illustrated by the otter, that is thoroughly at home in the river and may swim for miles out to sea, yet remains equally at home on land. On the next level may be placed the almost exterminated sea-otter (*Enhydris*) of the North Pacific, whose hind-feet are suited only for swimming. Then we reach the progressive series represented by sea-lion, walrus, and seals—the last almost as thoroughly aquatic as the whales, except that they bring forth their young on the shore and nurse them there.

MOVEMENTS OF MAMMALS.—Along with habitats should be considered the different kinds of movement. When the body is of considerable size and the movements are very rapid, there are usually long limbs, and the bones of the palm and instep regions (metacarpals and metatarsals) have a more or less upright position and tend to be reduced in number. In the horse there is for each limb only one such bone developed, and it is the third of the typical five. In cattle, sheep, deer, and the like there are two corresponding strongly developed

bones, numbers three and four, and these are fused together to form what is popularly called the ' cannon-bone,' in reference to its straight internal cavity. Another feature of this kind of swiftly moving mammal is the encasing of the ends of the digits in hoofs, and there is usually a reduction of the number of useful digits to two or to one. Thus, as we have said, the horse walks, jumps, gallops on the tiptoe of a single digit for each limb, and that digit is number three, corresponding to our middle finger or toe. When a mammal moves ' on tiptoe,' with the palm and instep portions off the ground, it is said to be **digitigrade,** as in horse and cow, and in cats as well. When the palm and instep regions are more or less flat on the ground, as in the bear tribe, the term used is **plantigrade.** We ourselves are plantigrade bipeds. Between these two extremes there are intermediate grades, as in the dog.

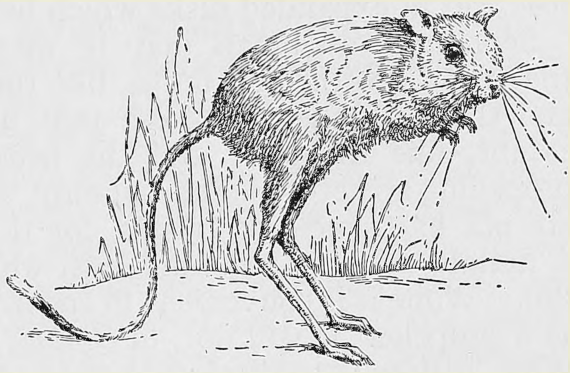


FIG. 272. JERBOA

Leaping along the ground is well illustrated by the kangaroos. A large kangaroo can cover fifteen feet in a bound and keep that up for a considerable time. In this rapid progression the stout tail is off the ground, but it may trail when the kangaroo is walking, and it forms one leg of the tripod when the animal is resting. Daintier than the kangaroos are the biped jerboas, which can take surprising leaps and are able to disappear like magic. In one of the common species, *Dipus hirtipes* of eastern Europe, the body is four and a half inches long and the tail seven inches. An interesting fact is that the jerboa-like bipedal habit and pose of body are exhibited by members of four different families of rodents and also by several marsupials from Central Australia. From different origins there have arisen similar fitnesses for similar conditions of life, and this is called **convergence.** Rabbits and hares resemble one another in many ways, and that is because they are near relatives. But there is no relationship between a jerboa and a jerboa-like marsupial, except that both are, of course, mammals. Yet they are like one another, being similarly adapted to similar conditions of life. An interesting leaping mammal is the Cape jumping hare (*Pedetes*), about seventeen inches long in body and the same in tail. It feeds on all-fours, but when it is startled it gets up on its hind-legs and takes enormous leaps. It is a burrowing rodent, often called the 'spring-haas.' These **jerboa-like mammals** of diverse kinds usually have the following characters in common: they live in deserts, they are nocturnal, they are sand-coloured

above and lighter below, they have long hind-legs and tails, and they have a reduction in the hind-toes, three being a common number.

Climbing mammals, like squirrels and tree-shrews, often show gripping nails. In the tree-sloths there are three or two great recurved claws. In monkeys the hands and feet have become in an unusual way prehensile, for the thumb, if present, can be 'opposed' to the fingers in all but the marmosets, and the big toe is opposable to the other toes. The long supple fingers are well suited for grasping the branch, and in many cases the tail acts as another hand. In the spectral tarsier, one of the quaintest of animals, the fingers and toes end in expanded disks which help in holding on.

Swimming mammals may be arranged in three groups: (*a*) those that paddle with their limbs, like the water-vole and the water-shrew and the duckmole; (*b*) those that also use the tail to an important extent, like the otter and the beaver; and (*c*) those in which the propelling structure is the tail only, as in whales and dolphins. These are not hard-and-fast groups, for the propeller of seals, for instance, is mainly made of the hind-legs, which are bound up with the short tail. While it is convenient to speak of the tail of a whale or a dolphin as a propeller, it will not, of course, be thought of as turning round. What it does is to displace masses of water first to one side and then to the other in rapid alternation.

Parachuting has been often tried by mammals, among marsupials, among rodents, and among insectivores. It seems very likely that the habit arose at least eight different times. It always means that there is an extension of the skin to form a 'vol-plane,' which supports the animal as it launches itself from tree to tree, from a greater height to a less. The 'colugo' or 'flying lemur' (*Galeopithecus*) of the Malay Archipelago, an animal about the size of a cat, can cover seventy yards. The flying phalangers of Australia vary from the size of a cat to the size of a mouse. They are very active in the evenings, swooping from branch to branch. It is useful to make a list of these parachutists just to show how the same adaptation may reappear in unrelated forms. As we have said, this is technically called **convergence.**

Swooping or Parachuting Mammals

Galeopithecus or *Colugo*	Probably to be ranked as a very peculiar Insectivore.
Anomalurus, *Petaurista*, *Sciuropterus*	'Flying squirrels,' among the Rodents, but differing markedly from one another.
Petaurus, *Aërobates*	'Flying phalangers,' all of them Marsupials, but not nearly related to one another.

Flight among mammals is confined to the bats, where a fold of skin is stretched out from the shoulder by the arm and outspread fingers, and extends on to the ankle, and between the hind-legs to the tail, if tail there be. It is a skin wing, not a feather wing, but it strikes the air effectively. The span of the outstretched wings in the smallest bat is only two inches, but in the largest fox-bat it reaches five feet. Not only do bats fly quickly, with quick changes of direction, but some of the large fruit-eating ' flying foxes ' are able to fly far.

Illustrations from Various Orders of Mammals

GROUPING OF THE ORDERS OF LIVING MAMMALS.—At the bottom of the scale are the primitive egg-laying **Monotremes,** represented by the duckmole and the spiny ant-eater. Above them are the pouched **Marsupials,** of which the kangaroo is a type. The remaining orders are grouped as **Placentals,** in which there is an intimate connection between mother and unborn young. Of these, the **Edentates** (e.g. sloth) and the **Sirenians** (sea-cows) may be ranked as archaic forms. Higher up are the **Insectivores** (e.g. hedgehog, mole, and shrew); the **Rodents** (e.g. rat, mouse, vole, rabbit, squirrel, and hare); the *aquatic* **Carnivores** (e.g. seal) and *terrestrial* **Carnivores** (e.g. cat, dog, weasel, and badger); the **Ungulates** or hoofed quadrupeds (e.g. deer) and the **Elephants**; and, marking extremes of mammalian life, the Open-Sea **Cetaceans** (e.g. whale) and the winged bats. Then there is the great **Monkey** stock, including the old-fashioned lemur, the true monkey, and, highest of all, the anthropoid ape.

The New-born Kangaroo

The old view that the mother kangaroo takes her youngster (there is usually only one) in her mouth and places it on a teat in the pouch has been dismissed. Long ago all competent naturalists gave up the theory that the young one uses some internal communication between the oviducts or the vagina and the **marsupium,** since the pouch is simply a great depression of the skin surrounding the teats; and, while it would be rash to say that the mother *never* gives assistance, the modern view is that the new-born kangaroo creeps into its mother's pouch. A circumstantial account of what actually happens, given to the Zoological Society of London by Dr. W. D. Walker, an Australian physician, corroborates this opinion.

When about to give birth the mother kangaroo sits down on the base of her long tail, with the rest projecting flat on the ground between her legs. The blind and very naked young one, not much over an inch long, even in a big species, is liberated from the ' cloaca,' and begins

at once to crawl upwards towards the opening of the pouch. The mother licks part of the route, but does not touch or help the young one until long afterwards. The clawed fore-limbs of the new-born kangaroo are more strongly developed than the hind ones, and they are used in a 'hand-over-hand' movement, in which the mother's hairs are firmly gripped. There seems to be an inborn obligation or



Fig. 273. Kangaroos

tropism in the young marsupial to creep *upwards*, and this helps in a general way as an automatic guide to the pouch.

As there are many species of kangaroo, general statements are risky, but in some of the larger kinds the young one frequents the pouch for three or four months. After it has gained strength it comes and goes, and it is one of the quaint sights of the world to see a young kangaroo jump into its mother's pocket and look out tentatively. The mother is careful of her pouch-youngster; the father is said to be indifferent, and the fact is he has not much opportunity of making his progeny's acquaintance.

The Marsupial Mole

This is one of the rarest of living animals, and is rare even in its home in Australia. All the marsupials are Australian except the opossums

of North and South America and the little-known selvas (*Coenolestes*), which lurk as 'living fossils' in the mountains of Ecuador and Colombia.

The marsupial mole (*Notoryctes*), which should be called the 'mole-like marsupial,' is a quite extraordinary bundle of peculiarities. It is a unique and almost incredible animal. First described by Dr. Stirling in 1888, it formed an unexpected addition to the heterogeneous order of marsupials. The little animal is mole-like in size, in its cylindrical build, in its shovel-like hand, in the absence of eyelids and ear-trumpet, in its snout, and to some extent in its habits; but its resemblance is merely superficial, due to what is technically called **convergence**; that is to say, the true mole and Notoryctes are a little like one another because they are in some measure similarly adapted to similar conditions of life.



FIG. 274
MARSUPIAL MOLE (*Notoryctes*)

We were so proud when we got a specimen that we had its portrait painted, showing the somewhat barrel-like body, the horny shield on the top of the snout, the silky fur which had a yellowish to reddish colour that afterwards faded, a little of the short, ringed, leathery tail, and, very prominently, the big yellow nail on the thumb, which is of great service in digging. All this was carefully described, of course, by Dr. Stirling; but one must be pardoned for gloating over a treasure. Our next step was to send the specimen to Rowland Ward, the famous taxidermist, with the request that he would prepare a skeleton, stuff the skin, and give back the viscera in a bottle. All of this was done, and out of one there came three, so to speak.

When the skeleton arrived, not to speak of the internal organs (of course the muscles were lost), it was at once plain that the marsupial mole is anything but a mole. The skull and the teeth are very different, and so with the structure of the hand and, indeed, almost all the anatomical details of the body. The salient features are those that mark off marsupials from ordinary mammals. Thus the creature has a little pouch or marsupium, which serves as an external cradle for the young one after it is born. As there are only two nipples in the pouch, there is probably only one offspring at a time, but this is uncertain. The opening into the pouch is turned backwards, not forwards as in the kangaroo and the majority of marsupials.

Another of the many differences between the true mole and the Australian mole-like marsupial is that the latter has lost its eye altogether, whereas the true mole has a fairly complete eye, about one twenty-fifth of an inch in diameter, which Aristotle studied more than

two thousand years ago. It is unlikely that the common mole can form more than a blurred image, but the marsupial mole cannot see at all. The old question rises still: Did it gradually lose its eyes because it took to the underground world, or did it become a creature of the underworld because it suffered from congenital degeneration of the eyes? To many the second theory seems the more probable, and we think they are right. But who knows?

Very little is known about the everyday (or should it be everynight?) life of this remarkable animal, but there is some reliable information in *The Wild Animals of Australia* (Harrap), by Le Souef, Burrel, and Troughton. These naturalists tell us that Notoryctes, of which there are two species, occurs in the dry, hot regions of the interior, though approaching the coast along the Australian Bight and in the north-west. It does not burrow deeply, but keeps to the loose surface soil, where it searches for insects and their larvae. During and after the rains it comes to the surface, even by day, and moves slowly in a sinuous course with its belly pressed against the ground. It leaves a triple track, the broken side-lines marking the prints of the feet, the continuous middle one the drag of the tail. During occasional quick movements the blunt tail may be carried cocked up. At intervals the animal utters a slight chirping sound, but it cannot be called conversational.

An interesting fact is the feverish activity a specimen displayed when Professor Wood Jones managed for a short time to keep it in captivity. It was munching earthworms five minutes after it was unpacked from its box; it made terrific tours round its room, nose down, tail up; it was ' intensely, feverishly active,' thus resembling the common mole, to which, as we have mentioned, it is not in any way related except that both are mammals. Yet it did not resent being handled and it drank milk out of a spoon. Nevertheless, it seems likely that the marsupial mole, like the true mole, is a highly strung, nervous creature that has found a semi-subterranean mode of life a pleasant escape from the booming bustle of Wild Nature.

Marsupials, once widespread, were insulated in Australia, and there they flourished and evolved, exempt from competition with the ordinary placental mammals which had not reached Australia before it became a great island continent, and could not readily reach it afterwards. The suggestive general fact is that the marsupials evolved in many directions which look like anticipations of several of the unrelated orders of placental mammals. Thus there are carnivore-like marsupials, such as the Tasmanian devil; rodent-like marsupials, such as the wombat; herbivore-like marsupials, such as the kangaroo; mouse-like marsupials, parachuting marsupials, jerboa-like marsupials, and so on. And here perhaps is the greatest interest of that bundle of

oddities which we call Notoryctes: that it did in some measure anticipate the true mole, and thus won survival which has lasted even unto this day.

The Pangolin

Aristotle once hinted at the existence of something daemonic, rather than divine, in Animate Nature, and several shrewd observers have detected what seemed to them to be glimpses of a sense of humour. Did not Dame Nature smile to herself when she made such a whimsical creature as a sea-horse, a chamaeleon, a puffin, or a bat? All this kind of metaphorical talk, however, is simply man's way of trying to fit words on to something he does not understand—that quality of unexpectedness, daring, and originality which is seen in many of the novelties which have from time to time emerged. It may be said, no doubt, that sea-horses, chamaeleons, puffins, and bats are bundles of adaptations well suited to survive in particular conditions of life, and that the smile which we ascribe to Dame Nature's face is wholly on our own. Yet is this not to leave unrecognized the frequently *astounding* character of many of the new departures that have occurred and that continue to occur?

That life is changeful like Proteus is a central fact in Biology; but our present point is that the new tentatives are often very daring. To make a mammal into a flying creature, for instance, or to give a fish a prehensile tail like a monkey's! It does not seem very metaphorical to think of evolving organisms as artists in self-expression, and some of their tentatives are highly original. Some have been failures; many have suited their times, yet have not lasted; some have become masterpieces; not a few are works of genius.

All this is by way of introduction to the puzzling pangolin, which is certainly one of the quaintest creatures ever evolved. It is *outré* even when it is dead; it is like a caricature of a cripple when it hunches itself along; it becomes a riddle when it rolls itself up into an unopenable ball. In some cases, in adult African species, there is not even a stray hair on the outside of the scaly ball to tell the student of zoology that he has to do with a mammal.

The pangolin or *Manis* represents a special family in the ancient and very heterogeneous order of Edentates. There are about seven species, and though the strange creatures are not often seen, they have a wide geographical range—in Africa, India, Ceylon, Burma, Malacca, Java, Borneo, China, and Formosa. This wide distribution on the part of a slow-going, biggish animal—from one foot to five feet in length—indicates a strong foothold in the **struggle for existence.** What are its life-saving qualities? It is covered from head to tail

with brownish horny scales, overlapping like tiles, almost as hard as bone. When it rolls itself up, tucking in its head and tail, it is practically invulnerable. During the day it lies quietly in a burrow, for it is one of the walkers in darkness, reserving all its activities for the friendly shelter of the night. It draws itself along rather laboriously, the tail trailing, the head depressed, the body arched up in a steep curve like a croquet-hoop. Its fore-claws are so long that, when moving, it walks on the backs of them, and this keeps the points and edges sharp for burglaring the edifices of the white ants. Some species, it should be noted, are able to climb trees, and this is another advantage in life's struggle. On the ground the pangolin's quickest pace is about that of a man's slowest walk. The soles of the hind-feet are planted flat on the ground. So we see that the pangolin is saved by its armour, its power of rolling itself up, its nocturnal habits, and its quiet, slow-going ways. It is a living ghost whose nearest relatives—beyond its fellow-species in the genus *Manis*—are fossils.

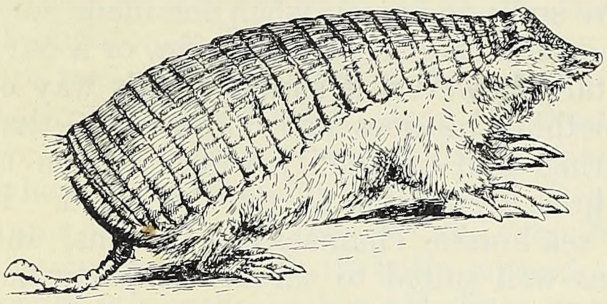


Fig. 275. Pangolin (*Manis*)

Many animals that have a firm foothold have also a long bill of fare, which is always a great advantage. But the pangolin is a specialist in its meals; it feeds almost entirely on ants and termites, which it catches with its long, sticky, worm-like tongue. The **diet specialism** is not disadvantageous in this case, for the hymenopterous true ants and the neuropterous white ants are very abundant in the countries where pangolins live; moreover, the gregarious habit of the insects ensures an abundant meal when the pangolin finds a hill. The earthen walls of a termitary, built of salivated particles of soil, are as hard as mortar, but they cannot stand against the fell scraping of the pangolin's fore-claws. Except in the embryo Manis there are no hints of teeth, but the large **salivary glands** on the posterior floor of the mouth (sub-maxillaries) cover the tongue with glue, which effectively entangles the booty. If some small pebbles are also whipped in, so much the better, for they will help to grind up the ants in the muscular, hard-walled stomach. As many as five hundred ants have been found inside one pangolin, many a ' pickle ' making a ' mickle.' It is said that a pangolin sometimes gets right inside a termitary and becomes a lodger, sleeping by day and feeding by night. But what we know of the masticating power of termites leads us to suspect that the lodger will soon find it convenient to take his leave.

Such a quaint creature as a pangolin is bound to have its myths,

and there is an amusing Japanese and Malayan one in regard to the ant-catching. The scales—somewhat like a giant's finger-nails—can be raised so as to leave a gap between them and the skin, and what the hungry pangolin does is to feign death with the scales upraised. The exploratory ants flock into the spaces and the pangolin shuts the doors. It then gets into a pool of water and raises the scales again. When the doors are thus opened, the ants hurry out of the prison, and when they rise to the surface they are devoured by the pangolin. If this was the creature's way of getting its daily bread, pangolins would soon be scarce indeed. It is true, however, that the scales can be raised and lowered, and Mr. Beebe tells us that when he put in the tip of his finger he got a very shrewd nip, which broke off a piece of flesh.

As to the significance of the scales there are two views. According to Professor Weber, a great authority on mammals, the scales are relics of a reptilian ancestry, and thus comparable to the scales on the toes of birds, which are also part of the reptilian entail. Both birds and mammals evolved from extinct reptiles. There are a few similar cases of the persistence of quasi-reptilian scales in mammals, and it should be remembered that armadillos are unique in having *bony plates* in their skin, which may be harkings back to the bony scales of tortoises and crocodiles.

But there is another theory that finds more support, that pangolin scales are secondary derivatives of hair-like structures. In the developing embryo, they say, it looks as if the scales were formed from the fusion of hair-like structures. The pangolin's hairs develop before its scales show; the unborn pangolin has a better equipment of hair than the adult. In the adults of the Ethiopian species there are sparse hairs persisting between the dorsal scales, and in all cases there are abundant hairs on the throat, on the under-surface of the body, and on the inner side of the limbs. Yet these hairs are without the usual sebaceous glands, except in the region of the snout. All this suggests that pangolins have suffered from some degree of hair-degeneration, and that the scales are not archaic relics of reptilian ancestry but secondary derivatives of hair-rudiments.

Pangolins have mediocre eyesight, a good sense of smell, and acute hearing—the last very useful at night. The cerebral hemispheres (q.v.) are well convoluted and hint at considerable intelligence; yet the cerebellum (q.v.) is quite uncovered, which points in the opposite direction. As a matter of fact, we know almost nothing in regard to the mind of the puzzling pangolin. What is its life but to sleep by day, to shuffle along by night, to rob an ant-hill and get a good meal, and so to bed? No doubt there are interludes, such as

finding a mate and rearing a family; but apart from anatomy, we must confess that we have said all we know about the puzzling pangolin.

The Manners of the Mole: An Insectivore

The mole is something of a conundrum. An old-fashioned mammal in many ways, yet highly specialized for life in the underworld. Very successful in the struggle for existence, as may be inferred from its frequency from Britain (not including Ireland) to Tibet, and from sea-level to Alpine heights of six thousand feet, and yet ' a bundle of nerves.' A strenuous creature, doing everything with zest, yet dying of disappointment if it does not get a meal every four hours or so. ' The blind one,' as it is called in many languages, yet with eyes, as Aristotle observed, showing the same parts as ours, except the lids. Without any trumpet or conch to its ear, yet acute of hearing, as Shakespeare knew:

> *Pray you, tread softly, that the blind mole may not*
> *Hear a foot fall.*

Though there can be few odour-wafting draughts in its subterranean retreats, the mole is keen of scent, and noses for earthworms and juicy grubs. To vibrations also, like the earthworms on which it chiefly depends for food, it seems to be exquisitely sensitive.

At first thought one might expect this burrowing mammal to be somewhat callous, for it would be trying indeed to human nerves to be so continually swimming in the dark earth, and that is what it comes to. Yet the mole is a highly strung, nervous creature, half-demented when one captures it, frenzied even when one puts it into a covered pail with plenty of earth, dying incontinently though one is careful not to do it any hurt. We once had one which seemed half-mad in its furious activity, and died almost immediately when we took it, not ungently, in our hand.

We have had considerable experience with living moles, and our conviction is that they are ' bundles of nerves '—timid yet passionate, fearful yet furious. Some naturalists have formed a different impression, but we have found the mole extraordinarily excitable.

It was probably through some hyperaesthesia of shyness, some shrinking from being seen, some deep-rooted agoraphobia or nervous dislike of open spaces, that they were led long ago to seek refuge in the underworld. What puts the mole about so much when one places it in the middle of the floor is not merely that the change from the cool, damp, dark earth to the garish day of the laboratory's wooden floor

is upsetting in the extreme, but that one is breaking in upon an ancestral shyness that led long ago to the adoption of a subterranean life. What we mean is that the mole is not merely shy because one takes it out of the ground, but that it went into the ground long ago because it was so shy.



FIG. 276. MOLE (*Talpa europaea*)

It must be remembered that moles often work near the surface, with their back showing at intervals when there is abundance of grubs, coupling worms, and the like on the ground or at a shallow depth. Their pairing, too, is in the open.

Moles embody the precept of doing everything with all their might. They burrow with zest, using their little hands for spades, as Mr. Masefield puts it, driving the earth to either side like a strong swimmer in the sea. Their breast muscles are like those of a Sandow. They toss the loosened earth impatiently upwards with their head and neck. They can turn through 180 degrees of soil with four strokes of their shovels! For their size they seem to be extraordinarily strong; they work as if they actually enjoyed it. The 'strenuous mole,' that is what *Talpa europaea* should be called; but the Gaelic name, 'black ploughman,' is distinctly good. How moles behave when we are not looking we do not know, but for civilized society they seem to be altogether too strenuous in their eating. They devour their food with too much gusto. One observer tells us how furiously her mole attacked a hen's head that it found in its demesne. Mr. Alston, who kept a mole alive for nine days, tells us of his captive's fierceness. When given the body of a frog, for instance, it seemed to be possessed of a devil, dancing round its booty, worrying and biting at the skin till it tore it open and reached the delectable organs of the interior. Thus, one of the difficulties in getting to know moles better is just this over-strenuousness. For even if a mole gets an enormous supper of earthworms before midnight, it may be found starved by next morning—with an empty stomach! There seems to be little chance of keeping captive moles alive unless one is willing to

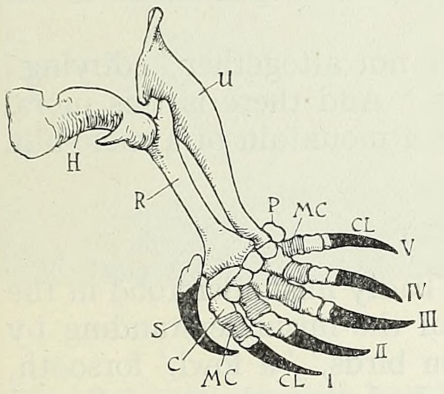


FIG. 277. FORE-ARM AND HAND OF MOLE

H, humerus; R, radius; U, ulna; S, special 'sickle' bone; C, carpal bones; P, pisiform bone; MC, metacarpals; CL, claws; I–V, the five digits.

get up several times during the night to feed them. And this is not the sort of night duty that one can readily devolve.

But our point is simply that to understand the manners of moles we must recognize not only their nervousness, but their strenuousness. They do everything, pairing and fighting included, with great zest. In Dr. Simpson's handy *British Mammals* we read that a mole can make a tunnel a hundred yards long in a single night, and that this feat would be paralleled in human terms if a man made a tunnel thirty-seven miles in length, with a diameter suited for his body to crawl in. But we suspect there is always a snag in these calculations.

No doubt if any creature deserves to be called indefatigable it is the mole; and the secret must be its fine constitution and perfect health. It is one of the most eupeptic of animals. One has only to look at its sleekness of fur to see that, and we have precise data as to its rapidity of digestion.

The mole follows an individualistic policy, and this is correlated in part with its innate *noli-me-tangere* disposition and in part with its mode of hunting for earthworms and the like. It must work alone in its tunnel. The female is a good mother, but she keeps carefully by herself before and after the young ones are born. For most of the year, indeed, moles are solitaries, and the little gentleman in the velvet coat is a bit of a free lover.

We must admit, we fear, that moles are not altogether 'edifying' animals, but they have much to teach us. And there is this moral to fall back on—that we should not make a mountain of a mole-hill.

The Bat as a Pet

There is no doubt that the bat has been badly misunderstood in the past. The Bible is responsible for some of the misunderstanding by including the bat among the 'abomination birds,' 'a fowl,' forsooth, 'that creeps, going upon all fours.' This bad example was followed by many of the poets, who ranked the bat as a beast of reproach—an 'obscene,' 'ill-omened,' 'dire imp of darkness,' or as a 'bawkie bird' of evil intent, apt to be a blood-sucker, as is indeed true of the South American vampire.

It is long since naturalists in their admiration of the bat lost all trace of vulgar prejudice, though, as man, one might wish that its skin were a little less entomological and its odour a little less pronounced. But one cannot have everything, and what a **bundle of fitnesses** is a bat! Think of the lightly built skeleton, the ingenious web wing, the exquisite tactility adapted to the dim light, the useful skin bag between the thighs, the cusped teeth so well suited for crunching insects, the keel on the breastbone for fixing on the flying-muscles,

the stiff backbone serving as a firm fulcrum for the wing-strokes, the life-saving hibernating habit, and the usual reduction of the offspring to one at a time. Even the peculiar ringed roughness of the bat's hair makes it easier for the baby to hold tight with its teeth and thumbs as its mother carries it about in erratic flight. What admiration is

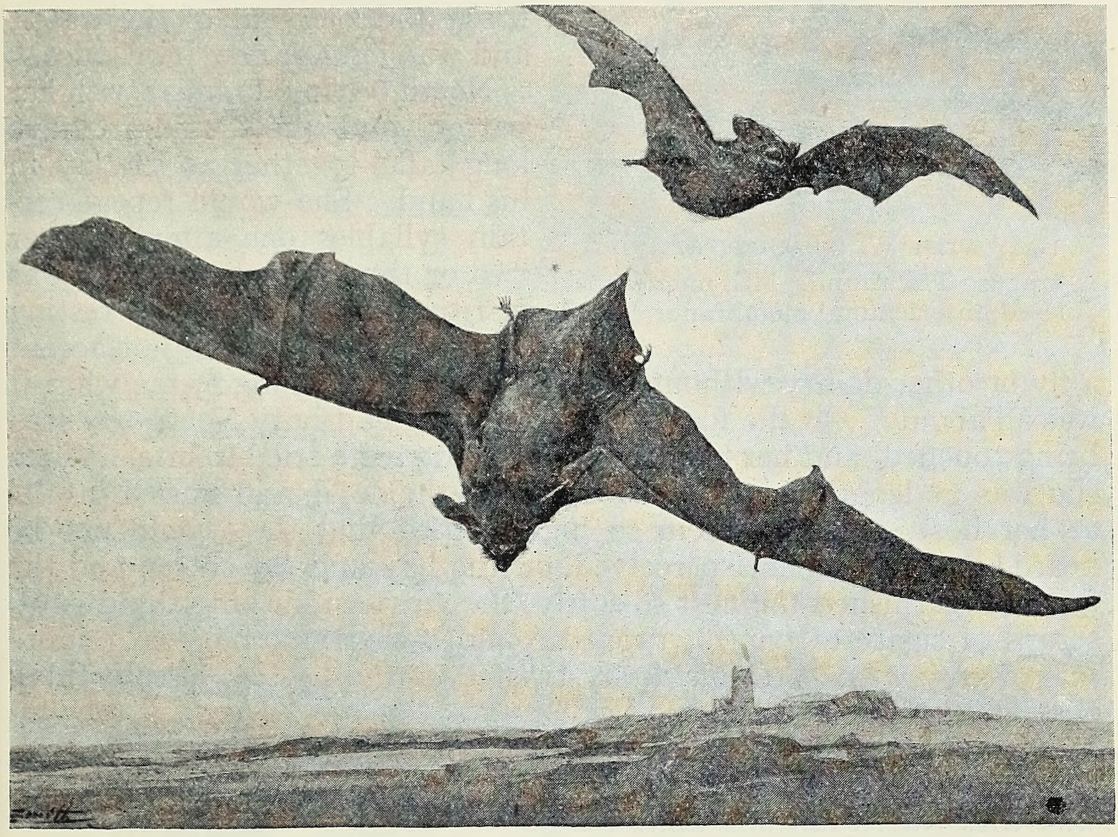


Fig. 278. Bats

due to a creature that hangs itself up by its toes and wraps itself up in its arms!

But it is easier to understand a bat's adaptations than to get near its personality. So we are grateful to Derennes for a study (*Life of the Bat*, 1925), half-artistic, half-scientific, in which sympathy is added to insight with very interesting results. The bat he chiefly studied he calls Noctu; one may perhaps identify it as a Scrotine. It had the muzzle of a bulldog and the ears of a pug, and it could not fly for more than ten minutes at a time, and never at a quicker rate than thirty miles an hour. In his boyhood Derennes 'tamed' this bat, establishing a bridge of confidence between himself and it, so that it allowed itself to be stroked with a finger, and learned to catch crickets and flies, rose-chafers and lady-birds, put into the cage. 'She adored

milk and licked it voluptuously from my finger dipped in the liquid; but I had to wet her muzzle several times in the saucer for her to understand and get used to feeding herself.' She took no pleasure in any nourishment that was not living and moving; she never of her own accord even touched fragments of dead flesh; but she took frisky tadpoles out of the water, and was fond of new-born mice.

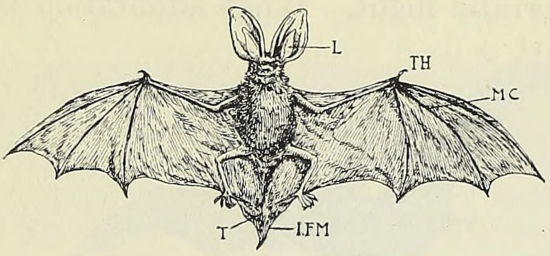


FIG. 279
BAT, WITH WINGS OUTSTRETCHED
L, tragus; TH, thumb; MC, metacarpal; IF.M, interfemoral membrane; T, tail.

Noctu became familiar with her patron, and they used to have long talks together as she lay in his hand. She would repeat certain syllables one after another two or three times, as if she was insisting upon some interesting point, and 'she would not accept a fly or other dainty without conscientiously explaining to me what it was all about.' On the fourteenth day of her captivity Noctu resented being touched, and her twenty-eight minute teeth tried to bite. When she was at length caught she fought like the devil, and hurled insults at her host, many of them so high-pitched that they could not be heard! 'It was then I perceived, on the hay and the cotton and the lint that garnished the nest so softly, the most astonishing thing—two scraps of cigarette paper wrapped round a cherry stone, two minute bits of grey *crêpe de Chine* drolly twisted at the bottom of something that looked like a sort of sombre face—and it moved feebly, and gave out tiny little cries.' That was why Noctu did not want to die. After eighteen days of nurture the young bat showed signs of becoming neurasthenic, so Noctu was allowed to fly away one evening, and her son followed her into the twilight, flying freely for the first time.

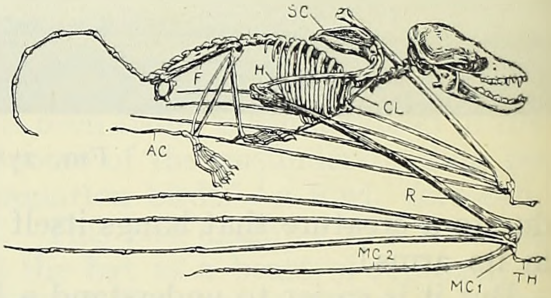


FIG. 280. SKELETON OF BAT, CREEPING
SC, scapula; CL, clavicle; H, humerus; R, radius; TH, thumb; MC1, metacarpal of thumb; MC2, metacarpal of second digit; F, femur; AC, calcar or spur.

Derennes began the study of bats in his boyhood, and he has kept up and extended his intimacy. He has shown hospitality to many individuals, and he knows three or four different species very thoroughly. It is therefore interesting to find him confidently maintaining that they are faithfully monogamous. There is 'absolute marital fidelity' through the four or five years of adult life. A quaint

detail is that if a bereaved male or female remarries it is always with youth.

Aristotle said that turtle-doves avoid the haunts of bats, and five centuries later Oppian repeated the story and spoke of ' this mortuary and sinister *bird*.' How terribly the innocent creature has been libelled! The bat comes in at the open windows and sucks blood from the sleeper; it lights on the wanderer's hair and there is parasitological infection; the industrious destroyer of mosquitoes spreads malaria; in short, the bat is sinister and should be crucified on the barn-door! All this is pitiable nonsense, of course; but it serves as the darkness against which Derennes's book shines out. The moral of his charming story of his pet bats is a fine commonplace: In order to love animals one must really know them. 'Between men and animals, as between men and men, evil speaking grows out of uncertainty, chiefly, and it is into ignorance that hatred and terror plunge their roots most energetically.'

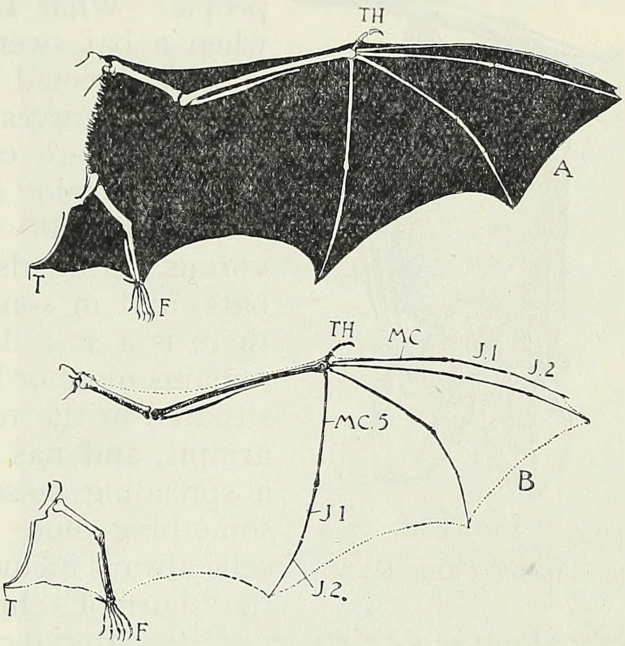


FIG. 281. WING OF BAT

A shows the patagium or fold of skin, beginning at the side of the neck, which passes along the margin of the arm, misses the thumb (TH), and is continued to the hind-limb (F). It is further continued to the tail (T) as the interfemoral membrane.

B shows the skeleton of the 'wing.' TH, thumb; MC, MC_5, metacarpals; J1 and J2, first and second joints of the digits; F, foot; T, tail.

THE FLIGHT OF BATS.—Every one is aware that bats flying at night, or in experimentally produced darkness, do not knock against obstacles. When wires are stretched across a room, bats avoid them, even in total darkness. The wires sound at the least touch, but there *is* no sound. It has been suggested that bats have very keen vision, but the capacity of avoiding obstacles remains when the eyes are covered. It is true that bats have an exquisite sense of touch, but they swerve from obstacles when at some distance off. Dr. H. Hartridge writes: ' Bats in full flight and in what appears to be absolute darkness can not only steer round a room and avoid one another, but they can also avoid obstacles such as threads. Further, they can tell whether a door is shut or open wide, or just sufficiently wide open to

allow them to pass.' Birds dash against the glass window of a room in trying to escape, but bats know better. We are not disposed to abandon the theory of a pressure-sense, allied to the sense of touch, but Dr. Hartridge has another suggestion. Bats have acute hearing, and they emit short-wave-length sounds which are near the audible limit of man, and indeed above that of some people. What Dr. Hartridge suggests is that when a bat swerves away from an obstacle it is being directed by a specialized sense of hearing. The waves of short wave-length which they emit are capable of 'casting shadows' and of 'forming sound-pictures.'

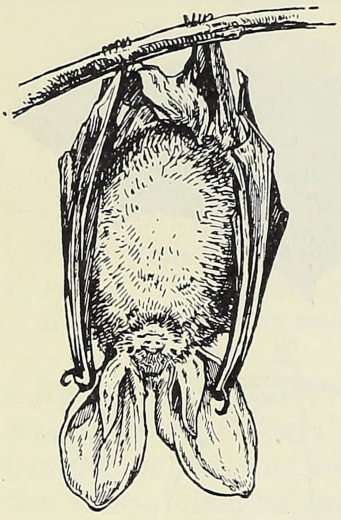


Fig. 282
Long-eared Bat

HIBERNATING GLAND.—In various insectivorous mammals, like the hedgehog, in many bats, and in some rodents, like the marmot, there is a so-called 'hibernating gland' which remains more or less of a riddle. It is usually situated in the region of the neck, breast, and armpit, and has sometimes the appearance of a spreading mass of brownish fat. But it is something more than fatty tissue, though its cells always include many fat-globules. During the marmot's hibernation the gland supplies only about one-thirtieth of the material consumed, so it is not an important food-reserve. It is rich in blood-vessels but it does not make blood. Its cells are crowded with small granules in addition to the fat-globules. There does not seem to be convincing evidence that it is a gland at all.

The Wild Rabbit: A Rodent

There seems to be good reason for believing that the wild rabbit lived in England before the Great Ice Age, that it was exterminated during that time of sifting, and that it was reintroduced—probably from the Mediterranean region or Spain. There is no doubt that its introduction into Scotland and Ireland is comparatively recent. Indeed, it was not known in Scotland before the thirteenth century, and there are many places north of the Tay which it did not reach till the nineteenth. But while it does not like severe cold, as in Scandinavia, it has an adaptable constitution and flourishes only too well in a great variety of places from Ireland to Australia.

The wild rabbit has no end of enemies, from man to rats, and yet it holds its own with ease. Against it are foxes, stoats, badgers, cats, hawks and owls, ravens and crows, and more besides, yet its ranks are not thinned. *In what ways does it secure survival?* Not because of

its wits, for it is not a clever creature, and its brain is very smooth. Not because of weapons, for its teeth are not suitable for biting (though it occasionally bites both man and dog in the extreme of its desperation), and it cannot give such a formidable back kick as the hare is able to do.

The first reason for the rabbit's success is its **fertility.** It is ready to breed at six months; it may have six litters between February and September; the period of ante-natal life is just about four weeks; there may be five to eight young ones in a litter. There is often considerable infantile mortality, for if the burrow gets very damp some of the young ones are apt to die of paralysis, and there is often the chance of a fatal visit from a brown rat. After they emerge into the open the young rabbits are often picked off before they learn to find their way about. Against all these chances of death there is a prodigious fertility.

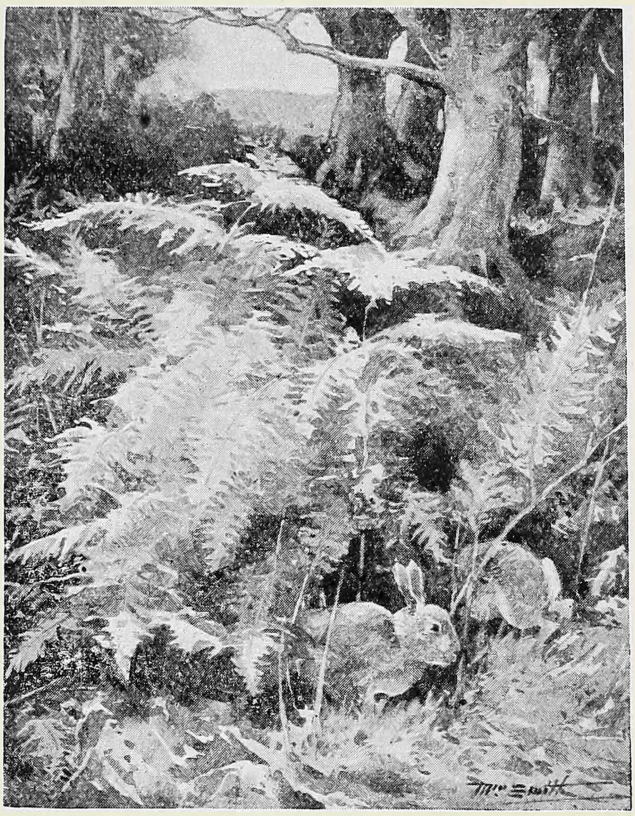


FIG. 283. RABBITS

A second reason for the rabbit's success is its catholicity of appetite, and this touches man on the raw. For besides grass, which is the staple food, rabbits are fond of cereals, turnips, bark, and garden vegetables. They eat the young shoots of furze and bracken, and, from the agricultural point of view, that is to the credit side of the account, but every one is aware of their very serious depredations in farm and garden. There are many curiosities of diet, e.g. birch leaves, laurel bark, and rhododendron, but these are neither here nor there except in indicating that the rabbit has many resources. A little detail which is quite characteristic of the difference between rabbit and hare is that the rabbit eats the whole turnip, whereas its relative—a dainty feeder—leaves the rind.

A third factor in the rabbit's survival is to be found in its **burrowing** habits. When animals long ago left the water and took to terrestrial life, they left behind them the universal freedom of movement which

aquatic conditions afford, and they were restricted to movement in one plane—the surface of the earth. This restriction implied increased danger, which had to be met by greater rapidity and precision of movements, implying improvements in the nervous system and the musculature. But another way out of the difficulty was to gain the power of flight as birds did, or to become arboreal as some squirrels have done, or to return secondarily to the water as in the case of otters, or to become burrowers like the rabbits. The burrow may be only a yard deep, but it is often much more; it may have various branches and more than one doorway. It is a life-saving retreat.

Another factor in success is in itself a confession of relative failure; the rabbit is in great part a twilight animal. Except when there is a tradition of great safety, rabbits tend to rest through the day and to reserve their feeding and their frolics for the dusk. It is then that the white tail, flicked up by the seniors, gives the inexperienced youngsters a lead in finding the burrow as quickly as possible. In the darkness there is also advantage in having well-trodden paths, or runways, though man knows how to utilize these in setting snares.

Another useful quality is **sociability.** Rabbits are in this respect to the hare as rooks to the crow. They are pleasantly playful and the social note is sounded in the quaint danger-signal which they make by thumping on the ground with their hind-legs. Compared with most gregarious animals, they have little voice, for it hardly rises above a whisper on ordinary occasions. They utter a grunt of contentment when they are well pleased and this is sometimes used as a call-note. Their scream of terror when the stoat overtakes them is of course pathological.

Yet another factor in survival is the care of the young. The nest at the far end of the burrow is made comfortable with soft hair pulled by the mother from her coat. The young ones, blind for eleven days, with closed ears for twelve, and quite naked to start with, are nursed very faithfully; a dead one is removed and hidden; the door of the burrow may be closed up when the mother has to go out.

Timid as she is, the mother will occasionally fight for her offspring. She will move them from a place of danger to a place of supposed safety, just as a cat will her kittens. And very important is the period of education, which begins when the young are able to leave the burrow. They have a great deal to learn and their mother is a good teacher.

It seemed of interest to discuss the wild rabbit from this particular point of view—how does it survive? The answers are because it is prolific, with a wide range of appetite, a burrower, crepuscular, sociable, maternal, and a good teacher. Of course that is not quite all—there is the keen sense of smell, for instance—but it must suffice; for there are some other questions to be considered.

There are well-authenticated cases where a pair of rabbits keep to monogamy for a year at least, but that is not the way with the majority. Polygamous is too mild a word; chance pairing is common.

Rabbits were introduced to Australia about 1850, and in the absence of their usual enemies they multiplied exceedingly, turning enormous tracts of useful soil into desert. Many checks have been tried, but the rate of multiplication seems to defy all expedients. The only hope of permanent relief, and that not a very brilliant one, is the increase of the agricultural population. But it is almost a vicious circle.

A typical wild rabbit is about seventeen inches long and three pounds in weight. Like the hare, and unlike other rodents, it has two pairs of upper incisors, the smaller pair behind the larger. On the lower jaw there is as usual a single pair of incisors. These front teeth go on growing persistently—an adaptation to counteract the continual wearing away at the chisel-edged tips.

It occasionally happens that the upper and lower front teeth do not meet one another with precision, and then the persistent growth of the teeth may prove fatal, though it is extraordinary what a rabbit can stand in the way of dental malformation. The chisel-edge is produced automatically because the very hard enamel is confined to the front and does not wear so quickly as the relatively softer ivory behind. In the process of eating it may be observed that the lower incisors work against the back part of the front upper incisors, and on the surface of the blunt, hidden second pair of incisors. There are, of course, no canines, and the furred sides of the cheeks project into the mouth between the incisors and the back teeth, which are suited for grinding. In rodents that gnaw much more than they wish to swallow, the non-edible material does not get past the front part of the mouth. The munching movements in eating seem to have given rise to a widespread belief among country people that the rabbit chews the cud (see p. 704).

It is interesting to peer into the grizzled greyish-brown fur of the wild rabbit to see what a subtle mixture it is. Students of heredity have shown that numerous ' factors ' go to the making up of this really beautiful fur, and that the dropping out of one or several of these in the maturing of the germ-cells may result in a colour-variety. So have arisen in domestication the blacks and whites, yellows and ' blues,' and other colours — all derived from the wild rabbit's fur. Should these varieties, which man keeps apart, interbreed, there must eventually be in the progeny a return to the wild rabbit type of coloration. Items that have been separated out come together again. The wild rabbit has evidently great possibilities of change, for it has supplied the material out of which man has established Angoras,

lop-ears, ' Belgian hares,' Flemish giants, and so forth. Small variations occur in natural conditions, but they come to nothing, apparently because the wild rabbit is well adapted to survive just as it is at present.

The circle of the wild rabbit's life cuts into that of man's. They do great damage by devouring field crops and garden-produce. They often smother good grass with the material thrown out from their burrows. They foul the grass so that sheep will not eat it, and even the hare sniffs and turns away. They destroy young trees by cutting off a ring of bark a little above the ground. There is, indeed, something on the plus side. They afford useful fur and palatable flesh; we have noticed that they check the spreading of gorse and bracken; and they make the most perfect golfing turf in the world. But even their best friends will admit that wild rabbits easily outrun all reasonable bounds.

The Common Hare

Early in spring the male hares or bucks are seen in the fields racing, jumping, bucking, and fighting. Their antics are referred to in the familiar phrase, ' as mad as a March hare.' The rival males fight with zest, kicking backwards with their powerful hind-feet as they leap over their rivals. But they also box and bite, and they may be so preoccupied with their passion that they will turn on a dog. There is not much timidity about a March hare; and it is not very easy to explain why the common hare should be timid at all. Is not the adjective an instance of man's way of reading himself into the beast? We see the hare's headlong pace, its unpredictable swervings, its rush up a hill, its long leaps, its feats of swimming—even in the sea—its nocturnal habits, and we say ' timid.' Did not Linnaeus call the creature *Lepus timidus*? But why should the hare be timid? It is very strong as well as swift; it can bite as well as kick; it is resourceful and wise. Was it not the original of Brer Rabbit? In the present-day nomenclature the common or brown hare is called *Lepus europaeus*, and the mountain or blue hare is called *Lepus timidus*.

Why is a hare not a rabbit? Or, if this seems a frivolous question, why do modern zoologists separate off the rabbits into a distinct genus, *Oryctolagus*? The answer is that hares and rabbits are not even cousins; they are more distant relatives. The hares rest in ' forms ' amid grass or bushes, whereas rabbits burrow; hares live for the most part alone, while rabbits live in warrens; young hares are born with a coat of fur and with their eyes open, while rabbits are born naked and blind; the ears and hind-legs of hares are much longer than those of rabbits; hares give a danger-signal by grinding their front teeth, while rabbits stamp with their hind-feet. So we might continue at con-

siderable length, but the root of the matter is much deeper: hares and rabbits differ in many details of their anatomical structure; and biochemical peculiarities, perhaps deeper still, are indicated by the contrasts of flesh and odour.

Too much attention has been given to the alleged occurrence of

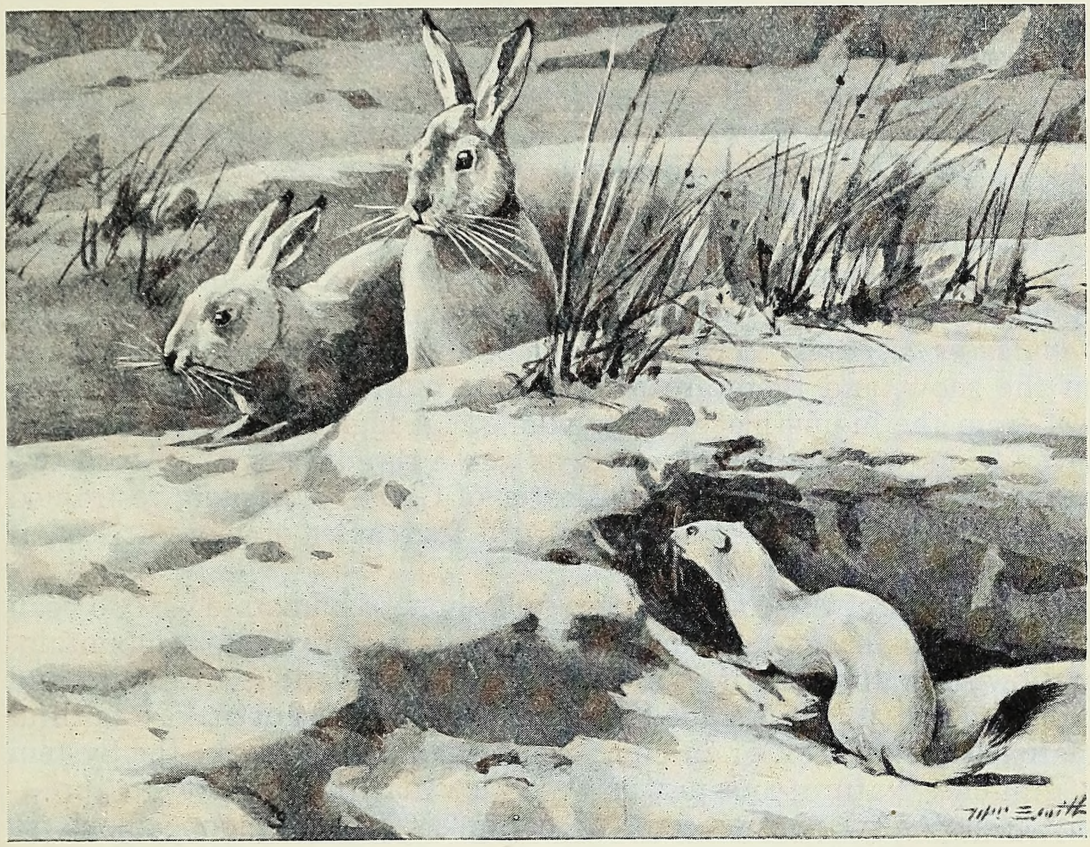


Fig. 284. Mountain Hares and Stoat

interbreeding between hares and rabbits, for the improbability of this is evident even from the slight contrast which we have just drawn. The two animals are widely apart and they are antipathetic. Hares do not even like to feed on ground which has been frequented by rabbits. One of Darwin's few mistakes was his acceptance of the evidence adduced for the origin of ' Leporides ' as successful hybrids between hares and rabbits. But no convincing evidence of even pairing is forthcoming, not to speak of hybrid offspring. The ' Leporides,' interpreted as crosses, are merely varieties of rabbit; and the same is true of the ' Belgian hare,' whose name has often led the unwary astray. It seems, however, well established that crosses occur between brown hares and blue hares; though even here there are more interpretations than observed instances.

From amongst the many excellences of the common hare we may select a few: the enviable strong heart that enables the animal to leap at once into top gear; the high pitch of the senses, especially of hearing and smell, so that it is practically impossible to catch a hare napping; the fastidiousness of its meals, which may help to account for the small number of unpaying boarders in the alimentary tract; the cleverness —instinctive if you like—of the creature, as shown, for instance, in criss-crossing its tracks, or in breaking the scent by taking a long leap out of and into the cradle, when there are leverets there; the devotion of the mother, as seen when she shifts her family, usually from two to four, if the fox discovers the secret, or when she breaks a stoat's back with a kick delivered during a flying leap.

The muscular development of a hare rouses one's admiration, and there is some significance in the absence (complete in our experience) of fat below the skin, where most mammals have more or less of a *panniculus adiposus*. Leaps of seven or eight feet have been measured on the snow, and there are records of a mother hare clearing fifteen feet from the hiding-place of her young. A high jump over a wall of seven feet six inches is chronicled, as also a run of twenty miles in two hours. The fifteenth-century ' Master of Game ' was more restrained when he wrote: ' A hare shall last well four miles or more or less, if she be an old male hare.'

In one respect the common hare falls short of human ideals. It can kick and box, it can race and clear hurdles, it can run up a mountain, and swim in the sea; it is alert and resourceful; it is obstinate and indefatigable; and it is a good mother. But it does not make a faithful mate. It takes a lot of different kinds of animals to make the System of Animate Nature; and just as we notice that this or that creature—say crane or swan, rhinoceros or orang—is strictly monogamous, so we must notice that the common hare is a free lover. Young leverets have been found in every month of the year.

To the Dark Ages, when the habit of looking at the facts was lost for so many centuries, we owe a legacy of errors about the hare; and these errors die hard. Thus many people still believe that hares sleep with their eyes open, which is certainly not the case; while others will not abandon Xenophon's theory that the long ears are used for steering purposes when the hare is going at full speed. The close resemblance between the sexes has formed a basis for the widespread notion that hares frequently change their sex, being in one month male and in another female. Change of sex does indeed occur in a few animals, but the hare is certainly not on the list. Nor can we agree with Leviticus xi 6, where it speaks of the hare ' chewing the cud.' The reference is probably to some other mammal with the same name.

THE BELIEF THAT RABBITS CHEW THE CUD.—Not long ago we

were asked by one of the ablest men of our acquaintance if rabbits chewed the cud. He seemed mildly surprised at the confidence with which we answered his question in the negative. It is interesting to find that this widespread belief is of long standing. It goes back to Gesner and Aldrovandus, and it is held by many country people to-day. Can the error be due to a misinterpretation of the munching movements characteristic of rodents? Or is it that some zoologists have promulgated the heresy because they found balls of food in the rabbit's stomach, which they could not account for except on the theory that the animals ruminated. It seems, however, that 'rabbits, especially young rabbits, when hungry, will swallow the faecal pellets, which may yield some nourishment after a second digestion.' It is sometimes easier to show that a belief is erroneous than to explain how it arose.

The Work of Beavers

Exaggeration is one of the sins that easily beset the student of Natural History, and beaver stories are mostly too generous. It is so difficult to keep from projecting the man into the beast. No doubt beavers are well endowed with instinctive cleverness in the way of making tunnels, cutting down trees, and building 'lodges.' Perhaps their gregariousness is also of service in keeping up a tradition of workmanship; for relapses have often been noted in the case of pairs living by themselves. It is certain that there is considerable variability in achievement, and there is great interest in records of beaver plasticity.

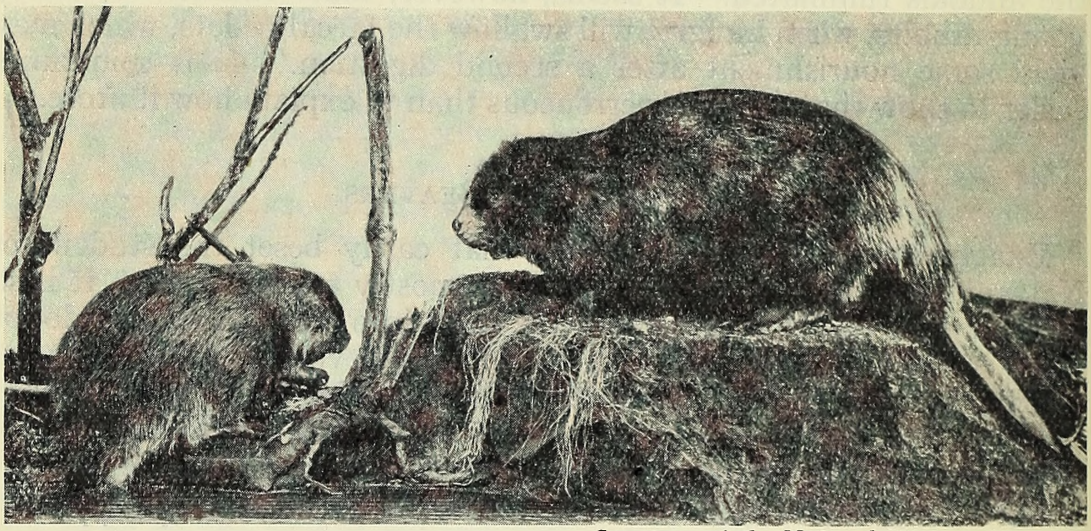
When they alter their dam or their home to meet special difficulties, they are probably getting beyond instinctive promptings, and advancing to genuine intelligence, which always implies some judgment.

It is probably true that many of the admirable things that animals do have come about by the acceptance and extension of some outside suggestion or hint. When a herring-gull lets a shell-fish or the like drop from its beak on to the shingle, so that it is broken, there is no need to credit the bird with thinking out the device. It is much more probable that the gull is accepting a suggestion from a chance occurrence, just as man has often done. It appreciates the advantage of having let its booty slip, and it goes on to form an individual habit. Similarly for beavers we venture to suggest that making a dam, which is often across a very narrow stream, may have had its basis in a natural accumulation of brushwood and soil, such as is often seen after a spate. And as beavers tread down little pathways among the trees when they are carrying pieces of branches to the lodge, or take advantage of ditches in which friction is reduced, the suggestion of a canal is not far to seek. To find a natural beginning of this sort does

not lessen our admiration for a long canal involving a large amount of co-operative digging and some conquest or circumvention of difficulties. Particularly admirable are canals which are not justified until they are completed, as in the case of a cutting right through a large island in a river.

But let us think over Mr. S. Stillman Berry's study of a fine beaver-canal in Montana.

The canal that Mr. Berry has studied opens into the Musselshell River, a tributary of the Missouri. It runs from the river straight into



Courtesy of the Natural History Museum

FIG. 285. BEAVERS

the native tangle of a cottonwood forest, and it was mistaken for an irrigation canal when it was discovered by chance in 1916. Some of those who first saw it ' expressed a wonder as to who could be running so well-constructed an irrigation ditch through that particular piece of forsaken jungle, and more especially how it could have been constructed without their knowing.' All round about near the river there was abundant evidence of the activity of many beavers—namely, lodges, dams, trails, slides, food-piles, and abandoned stumpage. Of course the beavers themselves are rarely on the stage except at night.

But there was clear proof that the part of the canal next the river was being used at the time for the floating of considerable quantities of felled timber, and the purpose of the canal was plainly to facilitate the transport of the cut wood from the interior of the jungle. The crescent-shaped, definitely cut canal led from the river into a natural slough curved in the opposite direction, and this slough seemed to have been flooded, and even deepened, by the beavers. The slough led inland into a much narrower canal, which passed by way of an ephemeral rivulet into a mere beaten trail which finally lost itself

in the undergrowth 1,145 feet from the river. The details bear out what we have suggested, that a cut canal may arise as an extension or improvement of something already existing.

The most interesting feature of the Musselshell canal is the connection between the flooded slough and the river. For the beavers had to master two difficulties—the piercing of a low willow-clad ridge near the river, and the carrying of their watercourse across a miry depression or swale. The second was the greater difficulty. It might have been overcome, as in many other places, by running the canal along the edge of the miry depression, and banking it on the down side only. But this would have meant great toil. 'There was a better way to solve the problem, a way which any irrigation engineer would have chosen under the pressure of similar circumstances, and this was chosen by the beavers.

'They ploughed their channel right through the centre of the swale, and *banked both sides* of the canal.' The ledges forming the banks of the canal ran conspicuously through the miry swamp for a distance of 215 feet. If the big slough is counted in, the canal has a length of 745 feet, but the 215 feet of canal through the miry swale is undoubtedly the most interesting stretch. The piercing of the willow-clad bar into the river presented no difficulty, and then the system was complete.

The Lemmings

In telling the story of the Scandinavian lemming we shall keep entirely to the best-known species, the mountain lemming (*Lemmus lemmus*), which used to occur in Britain. It should be kept at some distance from the banded lemming of Siberia and North America, which puts on a white dress in winter. On the other hand, it has its close counterpart in the brown lemmings of Alaska and of most parts of northern Canada.

The common mountain lemming of Scandinavia is like a giant field-vole; that is to say, it has a broad head, a blunt nozzle, short ears, and a plump body. But its tail is only half an inch in length, to a body of about five inches; and the hair on the back and rump is long and loose. Its eyes are small beads; the soles of its feet are hairy; the colour of the fur is brownish yellow, with dark spots above and yellowish below. Lemmings are active little rodents, very alert and normally timid, pleasant to look at until they appear as a starving horde, hundreds strong, in a cultivated district. Their occurrence in huge numbers is so sudden that we can understand the old belief of the peasants that they fell from the clouds.

As lemmings do not form warrens, like rabbits, and do not seem to

be socially inclined, the mass-movements for which they are famous are the outcome of the union of many family parties into companies, and of many companies into an invading army. It seems a pity to blunt the good word 'migration,' so well defined in connection with birds, by applying it to the trek or march of lemmings. It is not a migration, because there is no ebb and flow between summer quarters and winter quarters, because it is not a regular seasonal mass-movement, and because it has no close connection with breeding.



Fig. 286. Lemmings

The true home of the mountain lemming is well defined. It is the northern sub-alpine region, where marshy and tussocky ground bears juniper bushes and the lichens called 'reindeer moss,' with alternating damper stretches where dwarf birches and cloud-berries rise amidst low grasses and sedges. With this sort of sparse vegetation the lemming is wrapped up, and it was on a similar stage that it used to live long ago when it was a British mammal. Perhaps it is the severe rationing that explains the fact that although the lemmings are represented over enormous areas, they are never in ordinary circumstances crowded. Each lemming requires an extensive preserve, and there is a surly individualism about them. Visitor-lemmings are not welcomed. As with mankind, the bread-and-butter factor plays a big part in making manners.

Lemmings belong to the vole family, in which there are frequent instances of prolific multiplication. Plagues of field-voles are well known. The biological interpretation of this is partly that, in the course of prolonged natural selection, variation in the direction of large families would have survival value when the chances of death were normally great. To this it must be added that prolific multiplication is easier for mammals with a somewhat low degree of

individuation and with a relatively short ante-natal life. But it is more difficult, we think, to account for the occasional floods of life. No doubt reproductivity is a constitutionally variable quality; it can also be altered, as in sheep, by nutritive changes; and a reduction in the number of enemies will also tend to raise the population. Yet when we add up all the intelligible causes of a 'lemming year' we are not sure that they are quite sufficient to account for the striking result. Normally, there are two litters in the year, with an average of five offspring, males predominating. One litter may follow its predecessor before the nest is empty. There is over-population, and there is not enough food to go round. In the neighbourhood of each set of burrows there are too many competitors. They overflow where there is any vacant ground with suitable vegetation; they get in one another's way. Some observers describe a low whistling, which is regarded as a symptom of unrest and anxiety.

The older naturalists regarded the march of the lemmings as a more or less concerted and organized trekking, but that seems out of keeping with their otherwise non-gregarious ways; and the probability is that the massing together is the outcome of mechanical difficulties in the way of all-round prospecting. Thus the contour of a narrow valley would tend to force the trekking lemmings—mostly adolescent, inexperienced starvelings—into a half-mad mob. There is no doubt that they sometimes press over formidable obstacles, through villages, across rivers, and into the sea, where they are drowned in thousands. But it is very doubtful whether we have any warrant for speaking of a migratory impulse or even of an instinct to go straight on at all costs.

As the lemmings press on, their ranks are thinned by their natural enemies, the carnivorous mammals, such as wolves and foxes, and the birds of prey, such as owls and falcons. Some are actually swallowed by reindeer! In the great majority of cases the trekking ends tragically, for such survivors as there are find themselves amid a vegetation that is unsuitable; and even if they settle down and have offspring they soon dwindle away. There is no dispersal of importance, and careful investigation shows that there is no return journey. We are speaking of the common mountain lemming or brown lemming.

There are two other facts that make a remarkable story more intelligible. The first is that the overcrowding is attended by the incidence of an epidemic that carries off large numbers. In all probability a weakening of the constitution through lack of food renders the lemmings susceptible to a microbe to which they are normally resistant. Secondly, Elton has shown a remarkable correspondence between lemming years and the abundance of Arctic fox-skins. As lemmings form the staple food of the Arctic foxes, the ups and downs

in curve of the fox-skin supply harmonize with the periodicities in the abundance of lemmings. In recent years the maxima have occurred every four years, and as the lemming years synchronize almost exactly in Canada and Norway, there can be little doubt that the controlling factor is climate. Thus, in a strange way, modern science brings us back to the old belief that the lemmings fall from the clouds.

Sea-lions at the Golden Gate

We have had the pleasure of watching the seals or sea-lions (*Eumetopias jubata*) which frequent the rocky islands close to the southern post of the Golden Gate—that is to say, the beautiful outlet from the great Bay of San Francisco into the Pacific. The little islands are so near the tip of the long peninsula, on which the city rises in characteristic steep terraces, that the seals can be watched from the shore without any difficulty; and this is a great delight. Their movements can be seen with the unaided eye, and more precisely with a field-glass.

There were eight sea-lions visible that morning, but, as we saw none at all the day before and as the photographs show a crowd, we suppose that their numbers vary with times and tides. The species, known to zoologists as 'Steller's sea-lion,' used to breed on these San Franciscan seal rocks, but their breeding-grounds are now restricted to the Aleutian, Pribilof, and other rocky islands of the North Pacific. In winter they come as far south as California and Japan.

They climb up the rocks effectively, yet awkwardly, lurching from side to side as they lever themselves on their enormous webbed feet. The only graceful part of their climbing is the sideways and upward movement of the head on its extraordinarily thick neck. When they rest, with the head erect, their pose may be called statuesque, especially when seen against the sky. When they stretch out at full length on a flat shelf, with the hind-feet and toes pointing backwards, they look like huge bolsters. We watched a big, dark brown male or bull, about twice the size of the females, which were also lighter in colour. The male has longish yellowish hair about his tremendous neck, and to that, as well as to the loud roar, the term 'sea-lion' may particularly refer. In the beautiful museum of the Californian Academy of Science, which is famous for its habitat groups, there is a bull sea-lion of this species which weighed 1,800 lb. before it was set up. So this is the largest representative of the group. We saw some much smaller, almost fawn-coloured individuals, which we interpreted as young ones, two or three years old, long past the true ' pup ' stage.

In contrast to their terrestrial awkwardness is their freedom in the sea, and we watched a big male coming in from the fishing—a very graceful monster!

In old days this species of sea-lion was of the highest importance to natives of the northern islands. Mr. E. W. Nelson writes: ' Food and fuel were obtained from their flesh and blubber; coverings for boats were made of their skins; waterproof over-shirts of their intestines; boot soles from the tanned skin of their flippers; trimmings of fancy garments from their tanned gullets and bristles; and thread from their sinews.' They were so useful indeed that their numbers were gradually reduced, and there are now hundreds where there used to be thousands, and tens where there used to be hundreds. At the breeding season, when they suffer most, the huge bulls resist intrusion violently, but they are said to be flabbergasted if the sealer suddenly opens an umbrella in their face. They need to share in the protection extended to their relative, the Alaska fur-seal (*Callorhinus alascanus*), whose fur is much more valuable, yielding fine sealskin cloaks.

When the breeding urge impels them, the full-grown seals usually move north, e.g. to the Pribilof Islands, but their range is much less restricted than that of the Alaska fur-seal. In general, the story is the same—the bull selects a territory on the shore; he attracts a harem of a dozen or so, whereas the Alaska species may have a hundred; both preserve and wives may have to be fought for, and there are many sanguinary scenes. For some weeks hunger is swallowed up by love, but in inverted commas if you will. When the woolly pup is born and begins to suck, its mother has to make frequent journeys to the sea for her food, so that she may supply the quickly growing youngster's needs. Apart from man, the sea-lion has practically no enemies, unless it be the killer whale in the Open Sea. Unfortunately Steller's sea-lion is valued for its oil as well as for its skin.

To avoid confusion, it may be mentioned that there may be seen on the Californian coast not only (1) Steller's species, which sometimes breeds well to the south, and (2) the precious Alaska fur-seal (*Callorhinus alascanus*), which does not breed except on Kamchatkan and Pribilof rocks, but (3) the smaller Californian leopard-seal (*Zoölophus californicus*), a monogamous species, and (4) the still smaller harbour-seal, a true *Phoca*, related to the common British seal. Once more, the famous San Francisco seals are Steller's sea-lions, the noble sentinels of the Golden Gate.

We look again at these huge seals on the rocks; what bundles of **adaptations** they are! The shape of the body is well suited for rapid swimming; there is a reduction of friction—e.g. in the small ears; the hands and feet are turned into powerful webbed oars; the muscular development is colossal; there is warmth-preserving blubber beneath the close-set, non-conducting fur; the teeth are well adapted for

gripping fishes; the moustache and whisker hairs or vibrissae are very sensitive to touch; and so on and so forth. How much would be left of a sea-lion if one took away all its adaptations?

In other ways they impress one with their peculiarities. They carry polygamy to an extreme, especially when we remember that

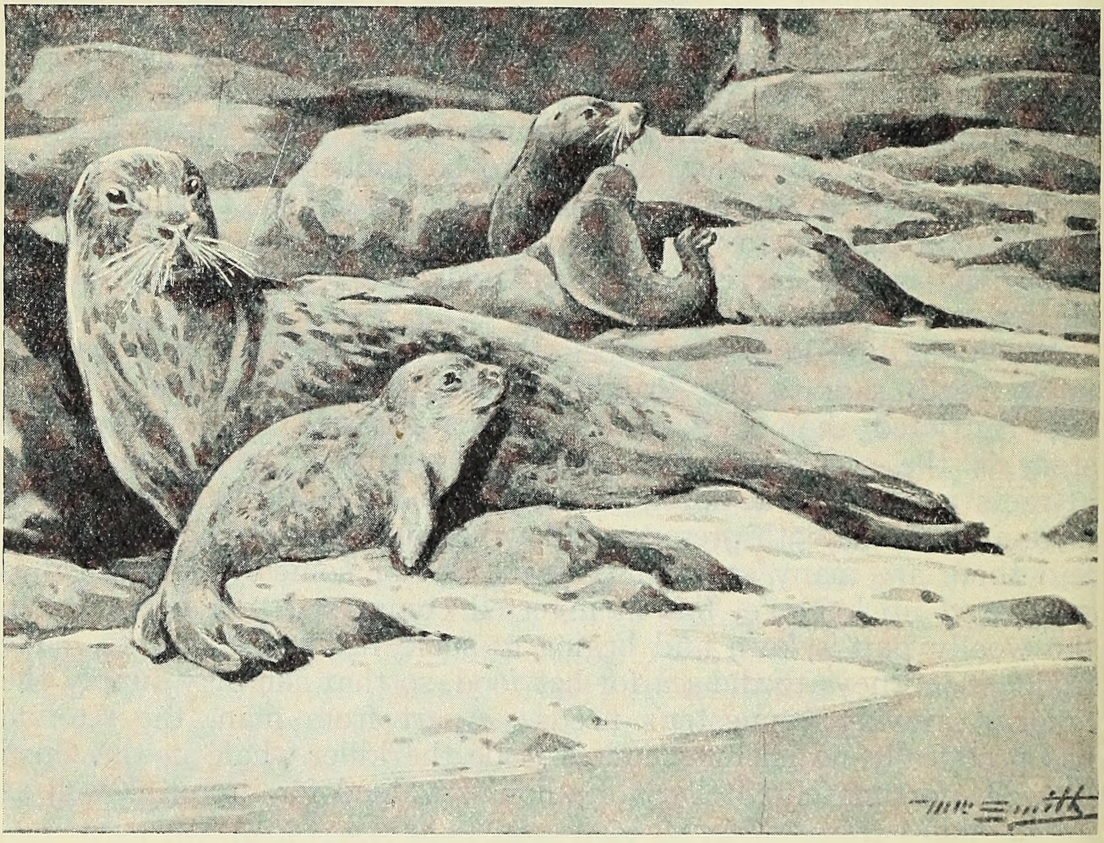


Fig. 287. Common Seals

they must be derivatives of terrestrial carnivores, which are usually monogamous. They are gregarious, which may be associated with the abundance of their food-supply, and with the restricted number of suitable resting-places. They must be relatively modern, these pinnipeds, as compared with cetaceans, for the mothers have to come ashore to bring forth their young, whereas the whales have learned to calve in the Open Sea.

The Walrus

It would be sad, if it were not such a tribute to genius, that to most people one cannot say 'walrus' without their saying 'carpenter.' Yet the animal is worth knowing for its own sake. In the first place,

it is unique. There are many seals, but there is only one walrus—only one species, we maintain—and soon, unless there are numerous and speedy St. Hubert conversions, there will be none. From many places in the North Atlantic and North Pacific, where there used to be great herds, the walrus has disappeared—a dismal and discreditable consequence of man's greed and short-sightedness. There has been none on Scottish shores since the publication of the *Origin of Species* (1859).

Once the unique *Trichechus* or *Odobaenus rosmarus* has passed, all the king's horses and all the king's men will not bring him back. It seems the lowest depth of stupid impiety to destroy a unique creature, the outcome of unthinkably long ages.

In the second place, the walrus is a masterpiece of evolution. It may not be beautiful—that is a question of taste—but it is a colossus and an artistic unity. 'Of all monsters that ever move upon land, the walrus is one of the most wonderful. A full-grown male is a living mountain of heaving flesh, wrinkled, furrowed, and seamed, ugly as a satyr.' We have our doubts about its ugliness, for that reproach is often a disclosure of the observer's very conventional way of looking at things. The walrus is, of course, very different from a red admiral butterfly, but the question is whether it is not in its own line an artistic harmony. The ugly is the discordant and the unfinished. As George Meredith said, 'Ugly is only half-way to a thing'; but the walrus has gone the whole way.

In shape like an exaggerated sea-lion, with a blunt, rugged head lifted five feet from the ice on a neck twelve feet in girth. A yellowish body, perhaps ten feet long, and weighing two thousand pounds. On the head two enormous upper canines projecting as tusks in front of the neck, the record length for a big male being half an inch over three feet. On the upper lip there is a walrus moustache, with some of the transformed hairs as thick as crow-quills! Both limbs are webbed paddles, directed forwards and outwards, very powerful in the water, rather awkward on land. There is no free tail, and there are no external ears. As the years pass, the hairs on the skin become fewer.

What do these mountains of flesh get to eat? They dig in shallow water for bivalves, which they crunch up, shells and all; they do the same with crabs and other crustaceans; they take shore plants and seaweeds for salad. In winter they float about on the ice-fields, keeping away from the permanent ice-pack, where they would starve. Dr. Hornaday tells us that 'in the long, hard winter of 1879–80, when the sea was frozen around St. Lawrence Island for many miles in every direction, the walrus herds were forced to remain so far away that all the inhabitants of the island, save one small settlement,

died of starvation.' There can be no doubt that man, in destroying the walrus, has destroyed many of his fellow-creatures who depended on the mammal for food, fuel, light, boats, dog harness, leather, and laces.

Like many of their cousins, the seals and sea-lions, walruses are socially disposed and congregate in herds. But they are not polygamous. The mothers are fierce and dauntless in defending their young from intruders, and will follow a boat in a fury, quite careless

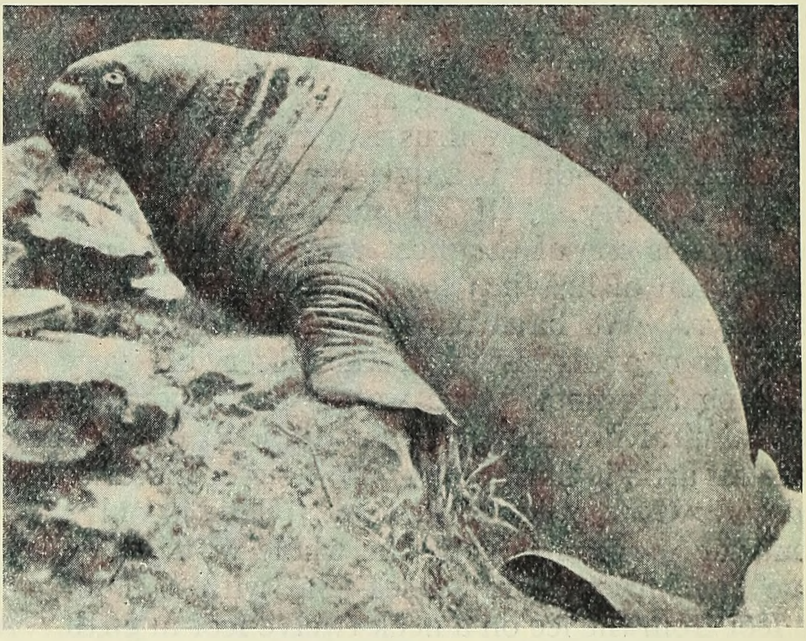


Fig. 288. Walrus

of personal safety. When a boat approaches a herd drawn up on the edge of the ice, the walruses 'plunge into the sea in a panic and rise all about the intruders, bellowing and rushing about, rearing their huge heads and gleaming white tusks high out of the water in an alarming manner.' But they take no concerted action, and if they break a boat it is more by luck than good guidance. Thus they have been regarded as stupid beasts, but this is probably a shallow Natural History. Few animals are cleverer than they need to be in their everyday life, and walruses, which have almost no enemies, cannot be expected to act with sudden intelligence when hunters shoot at them with rifles at close range. An animal may be well endowed though it fails to rise to the occasion when passengers on a Bering Sea steamer shoot at it wantonly as they go by.

Every animal of high degree is a bundle of fitnesses. Thus the body of the walrus, clumsy when out of the water, is well suited for the sea. The absence of external ears and tail implies a reduction

of friction; the paddle-like limbs strike the water with great force; the skin varies from half an inch to two inches in thickness; beneath the skin there is a layer of blubber, often six inches thick, which conserves the warmth of the body in the cold ocean. The ivory tusks are of service in digging up the molluscs. According to many hunters the walrus uses its tusks in hauling its ton-weight of a body out of the water and in climbing on the ice, but a careful naturalist with much experience of walruses never saw the animal use anything but its fore-flippers in pulling itself up. The soles of both hands and feet are corrugated and well suited for gripping the slippery ice. On the palm of the hand there is a special warty pad. As the old writers put it, the walrus is 'as large as an ox and as thick as a hogshead,' so it is a big bundle of adaptations. It is said to sleep upright in the water, but it is said to do many things that require looking into, such as drowning the polar bear. This is capped by the story that the bear kills the walrus sleeping on the shore by hurling a rock down on his head!

There is no doubt that some well-endowed animals like monkeys like fun and play practical jokes; but we have never felt convinced by anecdotes which are said to prove a sense of humour, say in dogs. A sense of humour is a very subtle quality, and it is not universally present in mankind. But many animals present humorous pictures, and the walruses one of the best. Several hundreds of them go to sleep along the shore of an Arctic island, and their convention is that when one awakens he gives his neighbour a dig with his tusks before relapsing into slumber. His neighbour does the same, and thus some member of the herd is always awake. It can be no mere coincidence that the walrus's one word is 'awuk,' uttered in a tone between the mooing of a cow and the deepest baying of a mastiff.

The White Whale: A Cetacean

This strange creature, also called the 'beluga,' often displays itself within sight of the liners that ascend the St. Lawrence. Its body is occasionally thrown up on British coasts and always excites attention because of its white colour. Indeed, the beluga has been called the 'ghost whale,' in spite of its very substantial solidity.

Various kinds of whales are not infrequent sights on crossing the Atlantic, and if one does not see much of the animal one cannot help noticing the column of outbreathed air that rises from the nasal openings or opening on the top of the head and often carries up some spray. For there can be no question of spouting water, in spite of Milton's rather terrible statement: 'and at his gills Draws in, and at his trunk spouts out, a sea.' A whale has no gills or trunk, and it

does not actually spout out more than water-vapour. The nasal passages unite into one external aperture in the toothed whales, but remain separate as usual in the baleen whales.

On the St. Lawrence, not very far from Murray Bay, some hours below Quebec, we got a good view of four or five white whales or belugas. As their movements seemed to be very sluggish, it was easy to make sure that we were not seeing the same whale many times. On an Indian-summer day, with the rather tawny water as quiet as in a pond, it was striking to see the white forms showing themselves above water in a most leisurely fashion. In the sunlight they appeared almost silvery. The length seemed about ten feet, but we could only guess. Larger forms are alleged, up to twenty feet, but there are not many seen over twelve. They rise somewhat high out of the water, so that a considerable fraction of their body is visible at once. There is no dorsal fin.

It is a sad reflection that if the white whale had been much larger than it is it would have been extinct long ago, for it is fond of sheltered bays and tidal rivers, and the younger ones at least can be caught in strong nets. The fishing is the easier because of the relatively lazy movements, and because white whales often work together in small schools of a dozen or so.

The proper name of the white whale or beluga is *Delphinapterus leucas*, but it is often called, quite appropriately, the white dolphin or white porpoise. It is the only species of its genus, and is definitely circumpolar in its range, frequenting the extreme northern coasts of the Old and New Worlds. As we had seen what to our inexperienced eyes appeared a giant iceberg as we entered the Strait of Belle Isle to the north of Newfoundland, we were not disposed to dispute the fact that these sluggards basking in the St. Lawrence, which would soon be sealed with ice, were characteristically Arctic. They are plentiful along the coast of Alaska, and may ascend the Yukon River for seven hundred miles. The Eskimos prize the flesh and oil, and harpoon the belugas from their kayaks or catch them in large-meshed nets of seal-skin cord. We heard of some beluga-fishing on the St. Lawrence. It would be a great pity to clear out these quaint creatures from what must be near their southern limit.

An interesting point about the colour is that the whiteness comes on gradually as the animal gets older. The young belugas are dark slate in colour. The change to milky white means a stoppage in the production of the dark pigment or melanin that is characteristic of blackish mammals and birds, and there may be an absorption of what has been already deposited in the young forms. It may be suggested that the low temperature of the far north has to do in certain constitutions with the blanching; and one recalls the polar

bear, the Arctic fox, the Iceland falcon, and the like. Melanins (q.v.) are probably derived in the body from the common amino-acid called **tyrosin** by the action of an enzyme (**tyrosinase**), and this action is perhaps retarded at low temperatures and in poor illumination. Some facts point in this direction.

One must not think of the white whale as an albino, in which the heritable factor for pigmentation has been somehow lost. It is rather an instance of a modification which is normally reimpressed on each generation. The young beluga has for several years been a slate colour; the adult is milky white; the normal modification probably includes the absorption of the melanin granules, and the stoppage of any further production of this dark pigment. Our speculation is to correlate this change with the low temperature. But this does not mean that no Arctic animal can be dark in colour. It is a question of individual constitution. To turn from speculation to experience, we envy Mr. E. W. Nelson the sight which he describes: 'During the twilight hours of the Arctic summer night, glowing with beautiful colours, the ghostly white forms of these whales breaking the smooth blue-black surface of a far northern bay add the crowning effect of strange unworldly mystery to the scene.'

How different was our picture—a broad river tawny with sediment, a brilliant day at the end of September, the banks in the distance transfigured in their autumn colouring, and these strange white whales rolling high on the surface for a second or two at a time. It is said that the creatures are far from timid. The members of a school raise their head out of the water, take a good look at the approaching boat, and then dive without flurry into safety. They feed on fishes such as cod and salmon, and on those that live on the bottom, like flounders, halibut, and eels. Perhaps this habit of feeding on the bottom may account for the quantity of sand often found in the stomach. Cuttlefishes and prawns are also included in the bill of fare. Speaking of eels reminds us of Dr. Hornaday's note that a fine specimen of white whale exhibited in the New York Aquarium in 1897 met its death in a curiously unpredictable way. A live eel got suddenly stuck in the beluga's blow-hole, and the mammal was suffocated before the fish could be removed.

White whales have a long pedigree, but they have not many peculiarities. The neck is more distinct than is usual in cetaceans, and the neck vertebrae are free instead of being fused as in other members of the order except *Platanista gangetica* or the blind dolphin of the Ganges. Perhaps the mobility is somehow correlated with life in relatively shallow water. Another peculiarity of the beluga is the possession of a distinct voice. Is there any other case among cetaceans? The sailors call it the 'sea-canary,' and it certainly utters 'curious squeaking

notes,' not to be confused, of course, with the 'sob' or deep sighing sound of the blowing.

HOW WHALES SWIM.—It is often said that whales swim by screw-like movements of the posterior body, displacing masses of water to either side alternately, and that the horizontal flukes of the tail are of use in balancing or in steering. There are several other things that are often said, and the reason for so much difference of opinion is that the movements, e.g. of dolphins, in swift swimming, cannot be followed

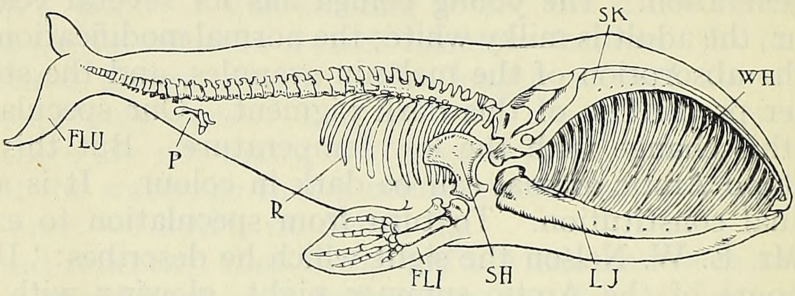


FIG. 289. SKELETON OF WHALEBONE WHALE

SK, skull; WH, whalebone; LJ, lower jaw; SH, shoulder-blade; FLI, fore-limb, a balancing flipper; R, ribs; P, vestige of pelvic girdle; FLU, flukes of tail, which form the propelling organ.

with the eye. The creatures seem simply to tremble, but they follow with apparent ease the largest steamship going at full speed. They can even keep up with a destroyer.

Dr. C. G. J. Petersen, Director of the Danish Biological Station, Copenhagen, has made a careful study of the whale's tail, and reached the following conclusions. In the elastic tail-fin itself there are no muscles, only four strong tendons, extending out to the terminal vertebrae. The tail-flukes are two halves of the propeller, but the engines working the propeller are the muscles of the posterior body. These muscles move the hind part of the body up and down; by its tendons the tail-fin is adjusted to a degree of rigidity corresponding to the speed. When a dolphin starts to swim, large vertical movements of the hind body are required to move a sufficiently large quantity of water, but, after the creature has put on full speed, say thirty knots or like that of a fast train, small but quick movements suffice, the tail-fin increasing in rigidity. Sideways or screw movements occur only in slow locomotion; tremulously rapid vertical movements give the dolphin its speed.

THE WEASEL: A CARNIVORE

Weasels are the smallest carnivores in Britain—in the world, indeed, as far as we know. The so-called 'cane' that some

people talk about rather vaguely as ' a small edition of the weasel ' turns out to be the female. We know, indeed, of some gamekeepers who will not budge from their conclusion that there are two kinds of weasel—a major and a minor; but there has never been any strict proof of this, though the name ' mouse-weasel ' for the alleged small species is widely used. We believe that the error rests on the differences of size according to sex and age, and on the occurrence of colour-variations. The true and only weasel is the whittret or futteret or mouse-hunter or fairy-hound. We do not know how many British aliases it has, but there are at least five in Latin, *Mustela nivalis* for choice.



Fig. 290. Weasel

The weasel is first cousin of the stoat (*Mustela erminea*), from which it can be distinguished at a glance by its much smaller body. The tail is also much shorter, only about two inches in length, and there is no black tip. Whereas the British representatives of the stoat species often put on a white dress in winter, turning into **ermine**, this is rarely the case among the British weasels. Yet the winter fur is paler, and in countries further north the change to white is normal. Most of the white weasels seen in Britain are **albinos**, with the red blood shining through their eyes, the ' factors ' (pp. 988, 996) for external pigmentation having dropped out of the inheritance. They are, of course, permanently white, and to be seen in summer as well as in winter. We must confess that we never saw a white weasel in the flesh. Some people have all the luck.

How does the weasel hold its own so well in a country so bloodthirsty and highly cultivated as Britain? How do its counterparts hold their own in the United States? Its snake-like body enables it to disappear into holes; we have seen one run right through a stone wall! Its swift movements enable it to efface itself like magic, and we suppose that the word ' pop,' in the familiar exclamation ' Pop goes the weasel,' refers indirectly to the animal's rapidity of disappearing. Purses used to be made of weasel-skin, so ' weasel ' might refer to money, and every one knows how quickly money vanishes. But this is a much-debated and not very profitable question.

Not only is the weasel a swift runner, it can climb and swim equally well. It can overtake the young rabbit, follow the field-mouse into its hole, and climb to a bird's nest on the branch of a tree. And

another quality that makes for survival is its long bill of fare, for it is known to catch half a dozen kinds of small mammals and as many species of small birds. It sometimes sucks birds' eggs, and it has been known to condescend to frog and toad. When a weasel kills a small mammal it usually bites at the back of the skull, a procedure that leads quickly to the brain; but an attack is often made on the blood-vessels of the neck. Of great interest is the device of gambolling before innocent birds,which sometimes become spellbound and allow the weasel or weasels to make an easy victim of at least one of them. This trick is also played by stoats.

Another predatory method that is hardly less surprising is hunting in little ' packs ' of five or so—perhaps in some cases a family party under the mother's charge. Richard Jefferies tells of watching five weasels hunting together in grim silence, but he quotes a countryman who saw a company of eight and heard them crying to one another with short snappy, sounds. The observer confessed that he got into a ditch as the eight weasels came along, for he had heard true tales of their attacking men. These creatures have not a particle of fear in their composition ! The ' packing ' is very interesting, especially when it illustrates something more than a chapter in the educational programme, for there are several kinds of carnivores that are solitary hunters for part of the year, and yet combine in the chase at other seasons. This is familiar in the case of wolves, which unite in packs for the winter. Millais refers to the west of England belief or superstition that packs of weasels hunt hares at night. Those who describe the wonderful sight speak of the little troup as ' fairy-hounds ' or ' dandy-dogs,' but we are afraid that it is a case of believing without seeing. A full-grown hare need fear little from a weasel.

While it is idle to pretend that weasels never do any harm to young game birds and the like, the evidence is conclusive that they do man a great service in destroying field-mice, voles, and even rats. It is always with regret that we see a weasel as an item nailed up on the gamekeeper's larder, for the weasel is pre-eminently *a killer of ' vermin.'* A stoat may do considerable damage to game and poultry, but the case against the weasel is very weak. This valiant carnivore plays an incalculably useful part in checking the multiplication of mice and voles. As to the charge of bloodthirsty ferocity which is sometimes brought against the weasel by namby-pamby people who are offended by the rough winnowing that goes on in Wild Nature, it is based on a misunderstanding of **the killing instinct.** Given the predatory instinct to fly at the throat of a plump young rabbit, one cannot be surprised that it should be evoked whenever the trigger is pulled. All these high-strung carnivores will kill and kill as long as opportunity offers, for they work reflexly, not reflectively, and cannot help themselves.

They simply have to go on killing in their instinctive orgy, even though they cannot use more than a small fraction of their booty. Except as regards rabbits, it is not often that weasels get an opportunity in Wild Nature for many kills in rapid succession; and man should blame himself, not the weasel, if he tempts it with flocks of young pheasants and the like. It may also be noted that weasels often store their superfluity, though it cannot, of course, keep wholesome for more than a day or two.

Against the weasel's fierceness we must balance the **maternal care.** In the beginning of summer, in Scotland, the young ones, four to six in number, are born in a nest of grass and leaves, hidden in a hollow tree, a secluded hole, or a stack of corn. There is usually only one litter in the year. The mother carries her young for about six weeks, but they are born very helpless and are not able to see for three weeks or so. For a while they get a gastric education on milk, but after about three weeks the mother brings them flesh. Their first voice is a whimper, which Mr. Douglas English compares to the sound made by rubbing a wet finger on a pane of glass; their second voice is a hiss; and to this much later is added an angry 'yap,' accompanied by a quick lunge. Speaking of the lunge and the recover from the hind-legs as a base, Mr. English writes: 'It is impossible to disregard the serpentine character of these tactics. Personally, I never could face the attack without flinching from its suddenness, unexpectedness, and vehemence.' The mother weasel will shift her brood, one by one, if the retreat is menaced, and, if need be, she will fight valiantly for them, careless of death. Young weasels are very playful and can be kept as pets. 'Delightful,' Dr. Simpson writes, from personal experience, 'cleanly in the extreme, as playful and inquisitive as kittens.'



FIG. 291. YOUNG WEASELS IN NEST

When early Neolithic man came to Britain after the last Ice Age —perhaps ten thousand years ago—there were weasels in the woods; and they are holding their own fairly well, for such reasons as we have explained. Little people they are, but great in spirit, fond of living dangerously, absolutely fearless, very keen of sense, quick of foot, nimble of wits, inquisitive, resourceful—wonderful little bundles of adaptations. And if they have made a fine art of murder, let us not

forget that they have made no less fine an art of mothering. So it is our hope and prayer, for Britain and North America, that no one will ever say: ' Pop goes the last weasel.'

THE SMELL OF THE WEASEL.—They say that if a dog has had a ' set-to ' with a little troup of weasels, it sometimes smells so vilely that it has to be kept out of the house for days. The odoriferous secretion or stink is well marked in the weasel, and is usual in related forms. Thus the polecat is also called the ' foumart,' which means ' foul marten.' The secretion is produced by a patch of glands which lead into a reservoir on each side of the end of the food-canal. A study of these glands—not a fragrant subject—has been recently published by a Japanese physiologist, Kawano, who has got some interesting results. The odoriferous glands are associated with lubricating glands, which open separately on the base of the anal papilla, and some of the latter are transitional between normal sweat-glands and the stink-glands. In other words, the odoriferous or stink-glands are specializations of commonplace skin-glands—another illustration of a common method in evolution, making a new thing out of something very old, and the specialized out of the generalized.

The glands are surrounded by a capsule of connective tissue and striped muscle, the latter accounting for the forcible discharge of the odoriferous secretion. This reaches an infamous climax in the skunk. The stinking fluid in the reservoir is an oily liquid of a pale glistening golden-yellow colour and a heavy appearance. But it is extremely volatile when it is discharged through the excretory duct, which opens on each side at the tip of the anal papilla. The glands are apparently insinkings of the skin of the anal region.

The odour of the fluid in the male of the Japanese *Mustela* has some resemblance to that of the explosion products of gasolene oil. That of the female is much more offensive and resembles that of methyl-mercaptan,[1] though not so strong in acridity. It would seem that the odoriferous glands have significance in the sex life of these animals, as well as being important in connection with defence and offence. Thus we see that there is considerable biological interest in the smell of the weasel.

The Skunk

The skunk is not one but many, but let us keep to the common skunk (*Mephitis mephitica*), for one skunk at a time is enough for our efforts at appreciation.

Give the devil his due, and give the skunk fair play. It is one of the most unpopular of animals, but it suffers from being misunder-

[1] A substance of the formula $CH_3.S.H$.

stood. The use of its name as a vulgar term of reproach lacks zoological justification. The common skunk is widespread in North America and very abundant, and in spite of terrible persecution it holds its own. Its body is a little over a foot in length, from the snout to the root of the tail; and the tail counts for another foot. The build of the body suggests a badger; there are very strong hindquarters; the elegant plume-like tail is the most notable feature. A plump old skunk may weigh ten pounds.

The colouring is a startling combination of black and white, arresting attention by day, and perhaps helping to warn creatures that require



FIG. 292. SKUNK

such memoranda that a skunk should be given a wide berth. Even in the twilight and moonlight it may make itself noticeable when it raises its bushy tail, which shows a good deal of white. There are two broad bands of white along the upper margin of the flanks, with jet black in the middle line between; and Alfred Russel Wallace regarded the pattern as a good instance of **warning coloration,** useful, like a visible hoot, in telling intrusive creatures to keep out of the way.

The word ' mephitic,' which is emphatically repeated in the scientific name, *Mephitis mephitica,* seems to mean a pestilential bad smell, and every one knows that this is of **survival value** to the skunk. If a stupid or hostile intruder will not recognize the skunk's right of way or the danger-signal of its raised tail, the mephitic non-resister turns sharply round and discharges two jets of a vile fluid which is not only nauseating, but blinding. The secretion is squirted, as if from a syringe, from a pair of glands at the root of the tail, and there is remarkable accuracy of aim. Dogs and men may suffer agony if

the discharge gets into their eyes, and the sickening smell is hardly to be exorcised from clothing. These evil-smelling glands are common in related animals, such as polecat, mink, and weasel, but they are highly developed in the skunk. Thus the surrounding muscles can drive the spray to a distince of ten feet or so. Like the voice of the bullfrog, the diffusing odour of *Mephitis* can be detected from the distance of a transatlantic mile. To Britons distances seem to be longer in America, but perhaps this is a relativity effect of America going faster than Britain!

The skunk is a very different kind of mammal from a mink, a polecat, or an ermine. It is slow-going, non-aggressive, and not very clever; inclined to be pacifist and saved by its exaggerated odoriferous glands. It usually moves in a deliberate, somewhat hesitating way, rarely getting beyond a slow amble; it has taken to walking in darkness; it asks only to be left alone.

But woe betide the intruder who will not take the hint!

The skunk's actual enemies are few—perhaps a great horned owl or a puma, occasionally a wolf or a coyote; it is saved from assault by its mephitic reputation. Its true nature is disclosed by the tame and playful young, by its behaviour as a pet (the odoriferous glands of course removed), and by the interesting way in which the four to ten young ones, born in spring, remain with their mother, sometimes following her in Indian file, through the next winter. When spring comes the apron-strings are cut, the family scatters, and the cycle begins again. When food is scarce and the temperature very low, the skunks may become comatose, like our badgers, but we venture to think that descriptions of their 'hibernation' require to be reconsidered. To be frank, we doubt entirely that skunks are ever hibernators in the Old World or the New.

Skunks are fond of chickens and young game birds, and it used to be the custom in America to shoot them on sight. But better acquaintance has shown that the skunk serves a very useful purpose in destroying injurious insects like grasshoppers and grubs, and in checking the multiplication of small rodents like mice. Far from being a pest, it destroys farm pests. Give a dog a bad name and we know what happens; and so false rumours gather round the unpopular skunk. Thus it is said that its bite causes rabies or hydrophobia. In all probability, however, this is a mistake due to the fact that the teeth of a somewhat indiscriminate eater are apt to be temporarily foul, the bite consequently giving rise to blood-poisoning. Apart from its teeth the skunk is a very cleanly creature.

In some parts of the world the fur-bearing mammals require to be kept in check, and trapping is legitimate as far as the continuance of the species is concerned. In most cases, however, it is not in

human nature to hold the balance, and the ranks of the furred creatures dwindle, till extinction is threatened or is actually effected. So it has happened that with the reduction of other kinds of furred animals in North America, skunks have become more and more valuable. Even they, however, cannot stand for many years an annual toll of fifteen million skins. As far as we can see, the only solution of the fur problem is to start more fur farms, and this is being done with skunks. They readily submit to semi-domestication, although tending to kill their own young ones; and there can be little doubt that, as the wild stock begin to decrease, the skunk farms will become more common, and will pay better. Perhaps an even better solution—which naturalists will welcome more than dealers in furs—will be the discovery that ladies may keep as pleasantly warm in winter, and look as well, without encasing themselves so obviously in the skins of mammals of high degree.

The Badger

The badger seems to be on the increase in various parts of Britain. The old-fashioned creature does almost no harm (even when at home close to a well-stocked duck-pond); it does no little good (e.g. in keeping down wasps and checking the multiplication of rabbits); it is an old-fashioned creature, a relic of old times; and it has very interesting habits.

The badger (*Meles vulgaris*) is an animal of long pedigree, a historical treasure which cannot be replaced if we allow it to disappear. It used to be much commoner in Britain, as the many place-names like Brockhurst plainly show, 'brock' being an old name for the badger. It is still far from rare in some areas, such as the New Forest, and Mr. Tregarthen, who has given many years to its difficult study, reports the persistence of numerous 'earths' in Cornwall and Devon.

The larger fauna of Britain was for the most part exterminated during the Ice Ages, when almost the whole country was thickly covered by great sheets of ice. After the melting of the ice there was a re-peopling from the Continent, with which Britain was still continuous. The badger was one of the mammals that returned at that time. Since the insulation of our country was effected there has been a reduction of the larger and finer animals. Many, such as wolf, bear, beaver, and reindeer, have disappeared again; others, like the badger, linger as rarities. Among the important reasons for disappearance or for reduction in numbers we must reckon the cutting down of forests, the spread of agriculture, and the persecution of creatures which were inimical to man's interests, or libelled as such.

The badger is at home in quiet, wild places, the spread of farms and villages and sophistication has been greatly against it, but it is not yet too late to save it for our descendants. We are trustees of the fauna, and it will be a poor business if we have to say that we have lost the badger (as we have lost beaver, reindeer, pine-marten, and others),



FIG. 293. BADGERS

and gained two species of rats, which are both aliens, not to speak of cockroaches!

What we have said in regard to the tendency to the reduction of the native fauna of this or any similar country, where man's operations are dominant, raises the question of the factors in survival. How is it that the badger, for instance, has not disappeared long ago? Part of the answer is as follows: The badger is in great part nocturnal, it is a creature of the shadows, it is inconspicuous in colouring, it is a burrower, it is very hardy, it has a long bill of fare, it is a good parent.

What is the indictment of the badger, in reference to which man excuses careless killing? It is said to devour game birds and poultry; and there is no doubt that it is occasionally carnivorous. On the other hand it is mainly a herbivore, and it often does no harm to poultry and the like when the opportunities are great.

The strong odour of the male is blamed for confusing the scent of

foxhounds. But this is a comparatively trivial matter when the risk of exterminating a very interesting animal is considerable. We do not mean that the badger is being hunted to death; what tells against the relic is its thoughtless destruction when detected on its peregrinations. We make no apology for badger-baiting, and we are not enthusiastic about fox-hunting, but it must in fairness be recognized that ' sport ' is rarely against the survival of a wild animal that is not markedly aggressive. In all probability we should have lost the fox long ago if it had not been for fox-hunting.

It is also said that the badger's extensive burrows are sometimes troublesome, as if they were common enough to write to *The Times* about. And some searchers for crumpled rose leaves have had their slumbers disturbed by the badger's cacophonous serenading about Christmas time, when its impulses move towards love-making. Some people expect the whole world to conspire towards man's comfort.

On the other side of the account, the badger, though mainly vegetarian, checks the increase of some troublesome insects like wasps, as well as of rabbits and other small mammals, of which it is easy to have too many. The badger is a scarce solitary, never numerous enough to do much harm, and the interest of his structure and habits affords sufficient apology for the occasional damage he does.

The Wild Cat

Apart from the majority of gamekeepers and sportsmen, every lover of wild life will be glad to know that the wild cat (*Felis catus*) is on the increase in Scotland, and is extending its range from the Highlands southwards. For it is nowadays the only British representative of the cat tribe of carnivores; it is an untamable wild beast—aggressive, alert, fearless, and hardy; and it is astonishingly handsome. The British list of mammals is so short that it is good news to know that the wild cat is more than holding its own at present. Although the total number is small compared with what it used to be when the forests were more extensive, it has risen considerably during the last few years.

The wild cat is practically, if not entirely, extinct in England and Wales. Those that are occasionally reported usually turn out to be feral domestic cats or their descendants, their increased size and strength being probably individual adaptations to a more strenuous life in the open. The problem may have been complicated by previous crosses between the true wild cat and domestic pussies that had reverted to independence. The probability is strong that our domestic cat originated in the caffre cat (*Felis caffra*) of Egypt and Nubia, and taming still goes on in the Nile valley.

Apart from the distinctive structural features of the wild cat, such

as the short, bushy tail, it is an intractable creature, not amenable to domestication. Moreover, the domestic puss was for a long time rare and valuable in countries like ours, where the wild cat was at home and while it was still abundant.

Nature has put its seal of approval on two contrasted ways of living



Fig. 294. Wild Cat

a free life—the each-for-himself policy and the mutual-aid policy. Each of these two policies may secure survival. They are suited for different methods of getting food, for different surroundings animate and inanimate, and for different constitutions. Thus, in stalking its prey an animal must work alone; gregariousness implies that considerable quantities of food can be obtained at once; a timid, fearful animal is not likely to be a success as a solitary, unless, indeed, it has some strongly marked safety-bringing attribute such as inconspicuousness or unpalatability.

No better example of the each-for-himself policy can be found than the wild cat. It stalks its prey—such as hare, rabbit, grouse, or ptarmigan—by sight, using every precaution to efface itself. When it is close enough it makes, with a cry, several surprising bounds, and its teeth meet in its victim's throat.

Few watchers have witnessed this; for in addition to the difficulty of being unobserved on the stage, the wild cat's stalking is usually at dusk or before dawn. Just as a domestic cat may kill a rat with one stroke of its paw, so the wild cat may give a knock-out blow to a grouse. The rapidity of the movement accounts for the momentum. The canine teeth are sharp stilettos, and, as every one knows, in the domestic tabby there are claws of steel within the velvet gloves. Those of the hind-feet in particular can be used if need be with deadly effect. The booty is then dragged or carried to a hidden nook where hunger can be satisfied in safety.

The wild cat has better sex morals than the tabby; it is **monogamous.** With the numbers of this solitary creature as they are at present in Scotland, it would be difficult for it to be otherwise. From two to five kittens are born at the beginning of summer, and they may remain under their mother's tutelage till September. There is usually but one litter in the year, and the solicitous parental care makes this birth-rate suffice to meet the death-rate and a little more. The care is chiefly maternal, but the father is said to share in bringing young rabbits and the like to the kittens when they are in process of being weaned. Most of the individualistic mammals make very good parents.

The wild cat is a great climber and is at home in the forests. Where these have shrunk it has sometimes continued to survive by finding shelter among the rocks and boulders. In some way or other, except when there are hen-roosts and the like to rob, it must have stalking-ground. When hard pressed in winter it will wander far, even swimming rivers and creeks, to find suitable hunting; but it returns to its home, which may be a fox's or a badger's discarded den, or a hole among the rocks or amidst the roots of an old tree, or a lair in the heart of a dense thicket.

Before the Ice Ages, when there were mammoths and cave-lions, hippopotamuses and rhinoceroses in Britain, there seems to have been no scarcity of wild cats. But with the elimination that the setting in of glacial conditions implied, the wild cat and all other mammals disappeared except from what is now called the south of England.

Yet again when the ice-sheets melted there was a re-peopling of the British area from the Continent, with which it was connected across what we now know as the North Sea. Wild cats were among the re-colonizing immigrants, and where the forests had grown they found a congenial home. They do not seem to have reached Ireland, though there was not then any insulation to prevent their spreading so far.

Later on, as the forests shrank and agriculture spread, the wild cat was forced further and further north, and became more and more of a rarity. In spite of its strength and skill, its sharp wits and senses, teeth and claws, its nocturnal habits and fearlessness, it has no chance

in a country where wild places become fewer and further between, and where man delights to shoot even what he admires. Yet in spite of all this, the wild cat is on the up-grade again, and is creeping stealthily southwards. This is partly due to a recognition of two facts—that the wild cat works towards the quietness of deer forests, and that the tax it levies on pheasants and the like is not really very serious.

Let us hope that another and better reason for the survival of the wild cat is being found in a growing appreciation of its value as an heirloom.

Hooped Mammals or Ungulates

This is a large and very successful order, mostly vegetarian, mostly suited for rapid movement on the ground. The digits generally end in hoofs or at least in broad flat nails. There are fine brains.

The **Even-toed Ungulates** (*Artiodactyla*) include pigs and hippopotamuses, the New World peccaries, the camels, the little chevrotains, which have a three-chambered ruminating stomach, and the *Pecora* (cattle, sheep, deer), which have a four-chambered ruminating stomach. Digits 3 and 4 reach the ground.

The **Odd-toed Ungulates** (*Perissodactyla*) include horses, tapirs, rhinoceroses, and their extinct allies. Digit 3 is larger than the others and is symmetrical on itself. It may be the only complete digit, as in the horse.

In the order Ungulates many authorities would include *Hyrax* (rock-conies and tree-conies) of Syria and Africa, and the elephants (*Proboscidea*) of Africa and India. There are also many extinct ungulates without direct descendants now living.

The Wild Boar

Of all Christmas dishes, none is more characteristic than boar's head. It used to be first at the feast and foremost on the board, and was carried in on a lordly dish at the head of a jubilant procession, the major-domo chanting:

Caput apri defero,
Reddens laudes Domino.

The boar's head was not only palatable fare; it was a symbol. Decked in bays and sweet rosemary, 'his foaming tusks with some large pippin graced,' it indicated the height of hospitality, 'the chief service in this land.' It also symbolized the success of the chase, man's mastery over the wildness of Nature. For it is part of the joy of the feast to celebrate the conquest of difficulty and the hunter's

survival after dangerous exploits, *reddens laudes Domino* ('giving praise to God') in a very pleasant way.

No one would go the length of calling the wild boar a noble animal, but it has many admirable qualities. It is a ferocious creature, dangerous to man and dog, with its formidable tusks. It is fearless in attack and defiant in defence. When it charges it gets up a great speed, and its weight of two or three hundred pounds gives it a terrific momentum. As Shakespeare said:

The thorny brambles and embracing bushes,
As fearful of him, part; through whom he rushes.

How fearsomely Venus warned Adonis of the danger of hunting the wild boar:

On his bow-back he hath a battle set
Of bristly pikes, that ever threat his foes;
His eyes like glow-worms shine when he doth fret;
His snout digs sepulchres where'er he goes;
Being moved, he strikes whate'er is in his way,
And whom he strikes, his cruel tushes slay.

Mr. Hamerton notices the strange self-depreciating shyness of the young Englishman who will call a boar-hunt, with its undoubted dangers, mere 'pig-sticking.' Such inverted hypocrites we are! Yet perhaps we owe something of our fear-scorning pose to the sifting that went on among our forefathers who faced the boar with javelin and spear, and who hunted for long ages without even a dog to help them.

Opinions will differ as to the propriety of calling the wild boar handsome, but he is undeniably an artistic unity—especially an old boar at bay, 'his jaws dripping with blood, his tusks as dangerous as the horns of a furious bull.' With advancing years he becomes more and more of a solitary, trusting to his own strength, careless even of the wolf. It is not fanciful Natural History to suppose that the more impressive wild beasts have a 'reputation,' and that must be particularly true of a creature like an old boar, with whom few would willingly seek an encounter. Perhaps the impressiveness adds to the reputation, for Hamerton, who knew his wild boars well, lays emphasis on the psychological effect which makes the creature appear even more formidable than it is.

In many parts of middle and southern Europe the wild boar (*Sus scrofa*) still holds its own, especially in remote places, where there is forest shelter and yet soil soft enough to allow of rooting. The species extends into Asia and the Mediterranean region of Africa. In Britain it lasted on till the end of the sixteenth century at least, and many place-names, like Boar's Hill and Swinton, recall its wide

distribution in bygone days. There seems good reason to believe that the early colonists of Britain effected the **domestication** of the wild boar in this country, whereas most of the other domesticated animals were introduced as such from elsewhere. The breeding of the domestic pig out of the European wild boar seems to have taken place in many different European countries, and there has also been mixture with another domesticated race derived from an Eastern wild boar called *Sus vittatus*.

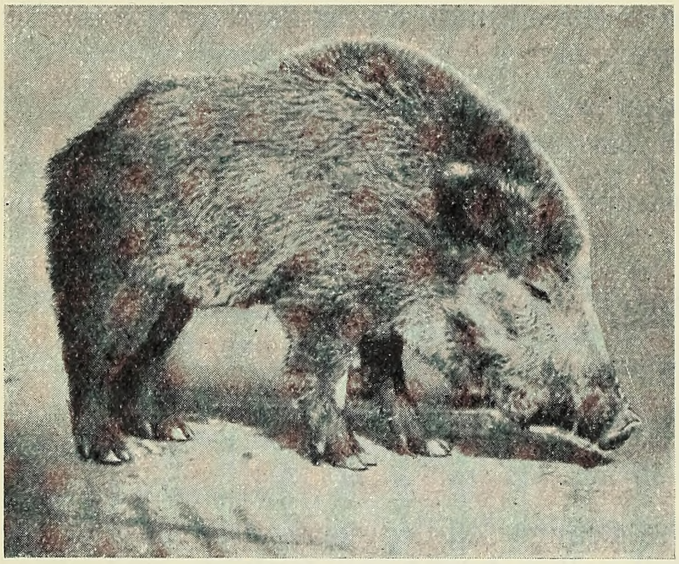


Fig. 295. Wild Boar

There is no doubt that wild boars were once very abundant. Thus a single hunt in Württemberg in the eighteenth century is said to have yielded over two thousand, and there are many similar records indicating the huge numbers that formed herds in the forests. They meant much in the way of food to our forefathers, and they have always afforded a justifiable opportunity for sport. They had to be kept in check, not only because of their aggressive fury when disturbed, but because, after agriculture began, they did much harm by trespassing on the fields and rooting up the crops. We can detect the poignancy of the lament:

> *That cruell boare, whose tusks turned up whole fields of grain,*
> *And wrooting, raisèd hilles upon the levell plaine.*

There are a great many stories, naturally enough, about wild boars, whose romantic suggestiveness has not been inherited by its lineal descendant, the common pig. One of these stories, told in Robert Chambers' *Book of Days,* is not unworthy of its subject. It seems that a boar's head is annually served up at Queen's College, Oxford, to commemorate a valorous act on the part of an old student of the college, and also to illustrate in passing the value of the classics. The student in question was walking in Shotover Forest, studying his Aristotle, as is the way with learned youth. All of a sudden he became aware of the glaring presence of a wild boar, who rushed at him with foaming jaws. With great presence of mind the collegian

thrust the *Ethics* of Aristotle down the boar's throat, or as near the oesaphagus as he could get. At the same time he uttered the exclamation: '*Graecum est!*' The result was happy, for the savage was choked by the sage, and the student went on his way rejoicing. The value of the classics!

It is interesting to notice that the young pigs, which are striped, are kept more or less in the middle of the herd, so that they are not easily caught by wolves; and there is much else that is admirable in the ways of the boar.

Deer or Cervidae

The deer form a large family of **ruminants,** such as the red deer (*Cervus*), the reindeer (*Rangifer*), the elk or moose (*Alces*), the roe-deer (*Capreolus*). They are widely distributed, absent only from the Ethiopian and Australian regions. The second and fifth digits are usually represented, by the side of the third and fourth which carry the hoofs. The horns, absent in the musk-deer (*Moschus*) and water-deer (*Hydropotes*), are **antlers,** solid outgrowths of the frontal bones, falling off every season, usually confined to the males or stags (except in reindeer). The earliest deer (Lower Miocene) had no antlers, thus resembling young stags of the first year; the Middle Miocene deer had simple antlers with one branch or with not more than two, thus resembling two-year-old stags. Thus there is a parallelism between the history of the race and the individual development, a **recapitulation** of the former by the latter.

THE GIANT DEER.—The skeleton of the extinct giant deer, which is usually misnamed the Irish elk, is something to gloat over, for it represents a majestic giant; and something to sigh over, for the species has long since passed from the list of the living. It used to occur in Scotland and other countries, but its remains have been found so abundantly in the peat-bogs of Ireland that it is always called the Irish deer. It ranged through northern Europe in bygone days, and it was one of the noble animals that our hunting ancestors had to reckon with when they explored Britain. It is quite likely that it was still going strong in Scotland when the Neolithic hunters arrived on the scene, perhaps ten thousand years ago.

We say ten thousand years ago, but the giant deer was not a very ancient animal as compared with an old-fashioned type like a mole. It was a Pleistocene or Quaternary mammal, flourishing in suitable regions during the Ice Ages, and not surviving very long after they came to an end. As the remains show, it lived in Britain along with the true elk or moose (*Alces machlis*) and the reindeer, but these companions survive, though no longer in this country, whereas the

giant deer has disappeared everywhere. Perhaps it might be called a short-lived success.

The skeleton of the giant deer is impressive; how striking the living creature must have been! It stood about six feet high at the withers, and so does the skeleton generously presented to our museum. The full-grown stag bore magnificent antlers which stood out almost at right angles, and had sometimes a span of eleven feet from tip to tip. That is to say, they approached the span of an albatross's outspread wings. We suppose that a pair of antlers on a red deer would be considered good to-day if they had a span of three feet from tip to tip, and that four feet at the withers would be considered a more than satisfactory height for a stag. It is clear, then, that the giant deer was a much more magnificent creature than its less extreme cousin. To be borne in mind, however, is the Scottish degeneration of the red deer, which has been mainly associated with the cutting down of the forests. The red deer is characteristically a forest animal, and it has lost vigour since the shrinkage of the forests has driven it to the more exposed mountains and moorland. A grand animal it remains, but some of the skeletons in the bogs show that its ancestors were more robust, taller in stature, and with stronger antlers. There are skeletons four and a half feet high at the withers, and the antlers are sometimes forty-four inches in span and in length. Their strength is sometimes very striking; thus in an Edinburgh specimen, dug from ' The Meadows,' the beam has a circumference of eight and a half inches above the second or bez-tine. According to Dr. James Ritchie, ' the old-time red deer was a third as large again as a selected modern example.' This careful naturalist does not attach much importance to the idea that the degeneration is partly due to the shooting of the finest heads, for the red deer is also stalked on the Continent, where its magnificence persists. ' The destruction of the forest has impelled the red deer of Scotland on a downward path, limiting its numbers, decreasing its range, and whittling away its former dignity by steps of physical decadence.' Its recovery of vigour when transported to more natural haunts in New Zealand is very interesting. This is becoming a digression, however, for the point we wish to make is simply that the giant deer (*Cervus giganteus*) was a far grander creature than the noblest specimen of the red deer (*Cervus elaphus*); and that is saying a great deal.

The Irish elk is not an elk (*Alces machlis*), but a deer, more nearly related to the fallow-deer (*Cervus dama*) than to any other. It does not really matter what one calls it as long as one knows that it is not an elk. With any name it stands magnificent, and the finest title it has ever received is *Megaceros giganteus*, the gigantic great-horn. Perhaps its most accurate English name is 'giant fallow-deer.' But enough of terminology!

Why did the giant deer become extinct? There may have been the beginning of a shrinkage of the forests which were its original home. It may have been harried by wolves and other large carnivores, and driven into marshy ground where it was trapped in the treacherous quags. It should be noted, however, that in Ireland the skeletons are usually found in the shell marl underlying the peat. In explanation of red-deer antlers found by themselves in peat-bogs, without any other bones, it has been suggested that the stags seek to allay the superficial irritation, before the antlers drop off, by plunging them repeatedly into soft ground.

But the question remains: Why did the giant deer become extinct, when red deer and reindeer, which lived along with them, remain well represented to-day? The answer is to be found in ' organic momentum.' As is well known, antlers are confined to the males, except in the puzzling case of reindeer, where they occur in both sexes. In ordinary stags the annual growth of antlers is activated by a hormone which passes from the male reproductive organs into the blood, and instigates an extraordinarily rapid and physiologically expensive development from the forehead or frontal bones. The stag's antlers are masculine exuberances, and they may remain undeveloped if the normal hormone is not present as a trigger-puller.

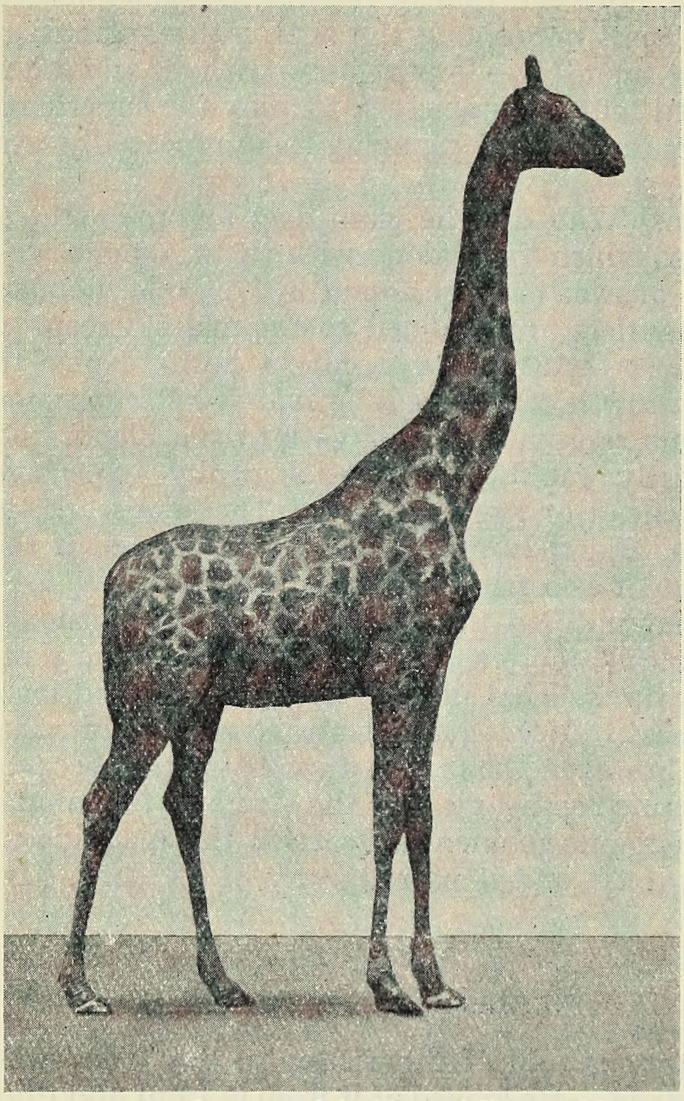
Now the virility of an animal and the production of sex hormones must be regarded as variable characters, and we may think of the giant deer as a highly sexed creature. That implied large antlers, and for a time there was nothing amiss. *Megaceros* was strong and could carry his fine head. Gradually, however, the tax on the constitution became too heavy; the animal became top-heavy, and the strain of the annual growth was too severe. Organic momentum carried the magnificent creature over the line of safety, and it passed away in its glory. Its epitaph is *Ne nimium.*

Giraffes

In various forms the story is told of the visitor to the ' zoo ' who came suddenly upon the giraffe. He looked at it from in front and from behind, and then walked away, muttering; ' I don't believe it ! ' That is certainly part of our feeling in presence of this quaint giant—so like an incredible creature from dreamland. Among living animals it has the longest of all necks, though with the same number of vertebrae as we ourselves have, and as the whale has, who has no neck at all. The head can be raised to a height of eighteen feet, and the creature can browse from above on the top leaves of the acacia trees. It is just as well that the giraffe likes to browse on small trees, for it has to spread out its long fore-legs when it wishes to nibble at something on

the ground—a disproportion of parts which we can see nearer home on a young foal.

The giraffe (*Giraffa camelopardalis*) is a true cud-chewer, but along with its fossil relatives, and the lingering forest okapi (*Ocapia*), it requires a family for itself. There are many peculiarities. Thus in the commonest species the paired **horns** are permanent bony processes, fused to the frontal bones, covered with unmodified skin, and similar in the two sexes. Between them there is a variable median bony prominence, and Sir Harry Johnston has described a Baringo species with another pair of horns above the ears, making five altogether.



Courtesy of the Natural History Museum

FIG. 296. GIRAFFE

'Giraffe' is said to mean 'he who walks swiftly,' and the animal can get up a speed of thirty miles an hour. In his sumptuous book, *Stalking Big Game with a Camera* (Heinemann, 1925), Mr. Marius Maxwell says that horses are of little use in the pursuit of giraffes for photographs; the giants must be chased in a Ford car until they are blown, or, as is equally probable, the camera lands in an ant-hill. In the giraffe's ordinary walk, with its strange combination of slouching and stateliness, there is a practically simultaneous forward movement of the limbs on each side. But the moment they are alarmed the animals break from this 'rack-like' walk into a 'transverse gallop' which, in spite of the great flourishing of legs, is singularly smooth, almost like 'gliding along.' The giraffe's gallop is practically the same as a horse's, the foot-impacts

succeeding one another as follows: near hind, off hind, near fore, off fore; or, when the animal is leading with the opposite leg: off hind, near hind, off fore, near fore. The only peculiarity, according to Mr. Maxwell, is that ' the stride which the giraffe, with its stilt-like limbs and comparatively short body, employs in its gallop necessitates the straddling out of the hind-legs to such an extent as to allow the lower part of the hind-legs, below the knee, to come slightly in front of the fore-feet, when the hind-limbs are fully drawn in and thrown forward.' The feet make a wide print on the ground, and when lifted quickly the pressure-spread halves of the cloven hoof come sharply together and sometimes make a clicking noise.

Giraffes, driven to their utmost, can keep up between twenty-eight and thirty-two miles an hour for a couple of miles or so; but even at their greatest speed ' they appear to be gliding along quite peacefully, and their actions give the appearance of being devoid of the least effort.' The animals utter no sound or cry during their gallop, and show no outward sign of fear or any other emotion. In their natural surroundings giraffes are gentle and placid, timid and unaggressive. Perhaps Pliny was not far wrong when he said long ago that the giraffe was as quiet as a sheep. This is not contradicted by the fact that captive specimens may lose their temper and kick their keepers viciously. They are nervous, high-strung creatures, and the conditions of captivity must often be galling—however humane the constraints may be. The technical name *camelopardalis* suggests a combination of the characters of camel and leopard, but the second reference was probably to the spots, not to the temperament. It must be admitted, however, that we do not know much about the home life of the giraffe. An animal chased in a Ford car has not time for many ' habits.'

The giraffe has a long prehensile tongue which it curls round the leaves of acacias and the like, and it chews the cud like other ruminants. Man has over 20 feet of intestine, which some people find too long; but the giraffe has 271 feet, 196 going to the small, and 75 to the large intestine. There is no word for this but prodigious; but the great length may be in a general way correlated with the vegetarian diet, for vegetable food requires to be exposed over a large digestive surface. As to the chambered ' stomach,' it should be kept in mind that in the cud-chewing animals the first three chambers—the paunch, the honeycomb, and the manyplies—belong to the gullet, and not to the true stomach. In other words, they have not glandular digestive walls, and are simply concerned with the storage and regurgitation of the hastily swallowed herbage.

One of the striking features of the giraffe is its inconspicuousness. Slouching along in the open, perhaps in Indian file, it obviously

challenges attention, and then, if need be, it finds safety in taking to its heels; but browsing among the acacia trees, an occupation demanding leisure, it melts into its surroundings and becomes invisible. This was brought out many years ago by Lord Delamere's photographs of giraffes browsing among the fourteen-feet-high mimosas, and has often been confirmed. How can such a large animal remain unseen? Partly because the light-and-shade effects among the trees are well suited to conceal animals whose rufous or tawny hide is covered with dark-chocolate areas surrounded by white interspaces; partly because the movements of the neck and head are sinuous and slow; and partly because the projecting heads and necks look like dead stems of the red-barked mimosa.

When we try to trace the pedigree of giraffes we come to Lower Pliocene extinct ancestors like *Samotherium* in Asia and in the island of Samos, *Palaeotragus* in Greece and Bessarabia, and *Helladotherium* in Asia. The last-mentioned had no frontal horns, and its neck was only moderately long. As the neck of the living Okapi, known since 1900, is not greatly elongated, the inference is confirmed that modern giraffes evolved from a stock in which the neck was not disproportionately long. The question thus arises: How did the giraffe attain to its extraordinarily long neck? According to naturalists of the very literal Lamarckian school, the lengthening of the neck is the result of the hereditary summation of minute increments due to individual effort in reaching up to the branches of the trees. But it is an assumption that even minimal elongations of vertebrae could be produced by individual stretching, and it is another assumption that such modifications, if they occurred, could be hereditarily entailed. Naturalists of the Darwinian school start with germinal or constitutional variations of hidden origin which affect the proportions of different parts of the skeleton. If a variation in the direction of a longer neck occurred in ancient giraffes, as occasionally in present-day men, it might be of critical value to its possessors. For although it would take myriads of years before the lengthening neck could reach the top of a fourteen-feet-high mimosa, it would be a distinct advantage to be able to reach even six inches higher than usual. And although the animal's endeavour did not directly produce the elongation, it is quite good sense to suppose that the variants tested their lengthening necks for hundreds of thousands of years, playing their hereditary cards, so to speak, to the best of their ability. Darwinism does not exclude this individual testing of inborn variations; indeed, it lays emphasis on it.

It has been shrewdly pointed out that the lengthening of the giraffe's neck, which we regard as a progressive constitutional variation, may have had some other use besides that of reaching the higher foliage. It may have served, like the ostrich's, as a sort of watch-tower, enabling

the steppe-land giraffes to keep a wide-awake, far-seeing eye on their hereditary enemies—the carnivores, such as lions and leopards. This sounds good sense.

THEORY OF CUD-CHEWING.—Here is food for thought, a problem to chew at, something to ruminate or ponder over of a long winter evening. How did sheep and cattle come to have this quaint way of eating their cake and yet having it? First of all, we may recognize the big Natural History fact that the herbivore is always threatened by the carnivore. Thus, unless there be unusual swiftness, as in wild

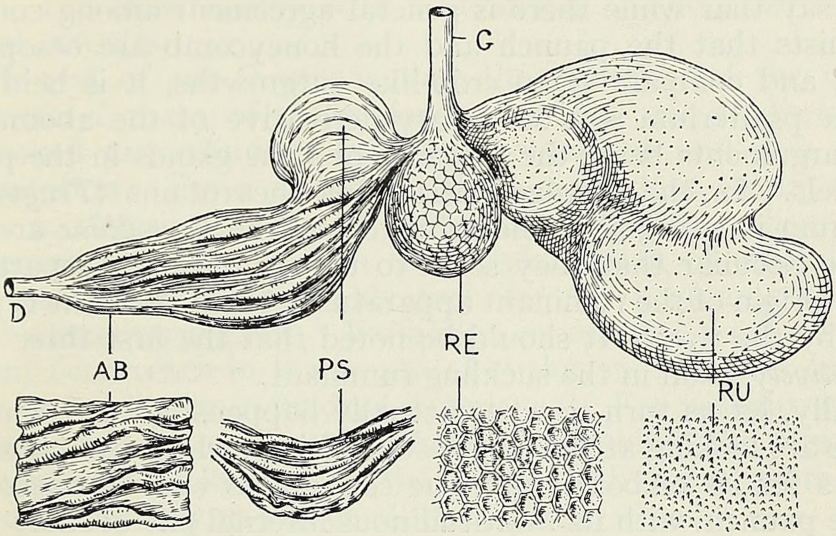


FIG. 297. THE STOMACH OF THE SHEEP

G, gullet; D, duodenum; AB, abomasum; PS, psalterium; RE, reticulum; RU, rumen.

A small portion of the interior surface of each compartment is shown below, on a larger scale.

horses, or some other life-saving quality, there is an obvious advantage in reducing the time devoted to grazing in the open, and of having some retreat, such as a thicket, in which to find shelter after a meal. Thus the cattle, sheep, antelopes, and other thoroughgoing ruminants or cud-chewers tend to eat very quickly in the open, to gorge their paunch with grass, and then to retire into safety to chew the cud at leisure. Familiar to us all in domesticated sheep is the way in which they settle down at the foot of a rock where they are safe from the hypothetical carnivore's surprise attack from behind. In conditions of domestication a bunker is as satisfactory as a rock to the bemused sheep, but that is just what the evolutionist would expect.

In the second place, let us recall the structures involved in the rumination; and it is of interest to learn from the histologist that the so-called ' stomach ' of the cud-chewer is for the most part a specialization of the lower end of the gullet or oesophagus. A study of the

minute structure of the walls has shown that the first three chambers (the **rumen** or paunch, the **reticulum** or honeycomb, and the **psalterium** or manyplies) really belong to the oesophagus, while the **abomasum** or reed represents the ancestral stomach. It is a familiar fact that the fourth chamber is the only one that secretes digestive juice. As many variations still continue to occur in the character of different parts of the food-canal of animals, there is no difficulty in thinking of the origin of constitutional or germinal variations in the area of the gullet in the ancestors of the cattle, sheep, deer, and their relatives. It is perhaps fair to say that while there is general agreement among comparative anatomists that the paunch and the honeycomb are oesophageal in nature, and comparable to crop-like outgrowths, it is held by some that the psalterium is a secondary derivative of the abomasum, one of the arguments being the presence of some glands in the psalterium of camels. In the strange deerlets or chevrotains (*Tragulidae*) the psalterium is vestigial. The arrangements in *Camelidae* are in many ways so peculiar that they seem to us to indicate a separate evolutionary origin of the ruminant apparatus in these aberrant types. But this is by the way. It should be noted that the first three chambers are *relatively* small in the suckling ruminant.

Thirdly, let us turn to what actually happens, always remembering that we are looking at the long result of time, which has taken millions of years for its elaboration. The cow grazes with business-like zest, and the paunch, with its multitudinous internal pile of short processes, becomes distended with grass. Having more or less satisfied its appetite, the cow seeks out a suitable spot, and settles down, inclined rather to one side. After a little while there is a somewhat hiccup-like spasm over the flanks and a bolus of sodden grass is seen passing up the gullet to the mouth. The complex regurgitating process has been very carefully described by Webster, but all that is very important just now is to bear in mind that it involves a succession of reflex movements, not to be thought of in any easy-going way—though they work very smoothly. It has taken ages to perfect the process.

With apparent satisfaction the cow chews the regurgitated grass, which by and by passes down the gullet for the second time. It does not enter the paunch, but passes along a groove to the third chamber or manyplies. There it is rubbed and pressed between the numerous plaits—quaintly reminiscent of a familiar musical instrument—so that what passes into the fourth chamber or stomach proper is a fluid mush, whose minute solid particles will soon be to some extent dissolved, in the ordinary course, by the various digestive ferments. Such in bare outline is the usual course of events in the process of cud-chewing. Now for our theory.

We wish to suggest that the evolution of cud-chewing began in a

regularization of vomiting. It would be more polite to say a regularization of hiccup; but it would be less defensible. For hiccup is mainly due to a sudden contraction of the midriff or diaphragm and an arrest of an inspiration which results in a characteristic sound. In vomiting, on the other hand, there is a strong contraction of the abdominal muscles and of the stomach muscles, as well as a contraction of the diaphragm. We hasten to note, however, that vomiting is not the right word either, for the regurgitation of the food in the cud-chewing is from the expanded end of the gullet and not from the stomach. The chief agency is to be found in the contraction of the abdominal muscles.

But the gist of our theory is that the repletion of the incipient paunch with a mass of green food, in which gas-production had begun evoked an irritation analogous to nausea and was relieved by regurgitation. For a long time there would not be anything so perfect as a compacted bolus of suitable size, and the reflexes would be less complicated, but it is in the regularization of an indigestion sickness that we may reasonably look for the beginning of a very profitable alimentary habit. Variations in reflexes must have been of frequent occurrence in the course of evolution, and these novelties would be tested in the individual experience. For without assuming any transmission of the direct results of new habits—the Lamarckian view—we must never lose hold of the idea of the living creature playing its hand of hereditary cards for all it is worth.

New reflexes that are very advantageous will be of survival value to their possessors, or will be carried for a while as correlates in the wake of variations of greater magnitude, big enough to be subject to Natural Selection. This Darwinian idea of the correlation of variations has not as yet received the recognition it deserves. If it be objected to our theory that it looks for the origin of a normal habit in a condition that is verging on the pathological, namely an abnormal state of alimentary repletion, it may be answered that we are supposing that novel reflexes, arising from germinal complications of the factors for the nervous system, were selectively approved of because they came to afford, as they increased, a more and more effective solution of a constantly recurrent condition of alimentary discomfort. Furthermore, there are many instances of the gradual regularization of the pathological, as we see in the periodic dying away at the base of the stag's antlers, or in the gluey threads which exude from the male stickleback's kidneys and are so useful in nest-building. We beg for some unprejudiced consideration of our theory that cud-chewing is a normalizing of a kind of vomiting.

The Donkey

We cannot but like the donkey. It is quaint, clever, affectionate, and philosophical. No doubt we have been party to the conspiracy to call it ugly, stupid, sulky, and dull; but we have known all the time that this is one of our traditional fictions. We accept it in our everyday talk, but we know that it is not true. In our estimate of the donkey, we must exclude, as for other domesticated animals, all those unfortunate individuals that are ill-bred, under-fed, and badly treated; but that is not always true even of the coster's 'moke,' which is often as engaging as it is well appreciated.

From the zoologist's point of view the domestic donkey is very satisfactory. Whereas the pedigree of the dog is somewhat perplexing, and the lineage of cattle is controversially complicated, the descent of the donkey, like that of the pig, is perfectly clear. In its structure the donkey shows a comprehensive similitude with the African wild asses, and there seems to be no warrant for dragging in the Syrian onager or any other species. The ancient inscriptions of Thebes indicate that onagers were tamed for centuries B.C., but there is nothing against the general verdict that donkeys are domesticated descendants of African wild asses. Perhaps there is room for difference of opinion when the question is raised whether the donkeys all sprang from the Nubian wild asses, or whether Somaliland asses, Masai asses, Maskat asses, and other African strains may not have had a share in the evolution. The variability of the domesticated forms suggests that several wild strains of *Equus asinus africanus* went to their making. It must be noted that during the five thousand years or so since the domestication of the wild ass began many breeds have been established in different countries, some dwarfish and others stately, some white and others black, some with a very distinct shoulder-cross, and others with transverse bands on the fore-limbs. Donkeys are not one but many, and they vary in temperament as well as in superficial features. As regards deeper structures, such as the details of the skull, there is great uniformity. In all essentials the donkey is a conservative type.

How does a donkey differ from a pony? We think at once of the long ears—'like errant wings,' as Mr. G. K. Chesterton described them—the long tail ending in a wisp, the upright mane, the dark shoulder-cross, and the absence of warts on the hind-legs. Whatever 'species' means, it is what is implied in the differences between horse and ass—a natural discontinuity which the artificially hybridized mules do but emphasize. When we dry the blood of a horse and of an ass we find that the crystals of haemoglobin differ in detail in the two species. We can hear the difference of species when we listen to a neigh and to a bray.

The donkey's ' hee-haw ' is one of the weirdest sounds in the animal kingdom—perhaps the strangest of kin-calls. As Phil Robinson says: ' I defy any one to hear a donkey fairly out and not to laugh at the cavernous melancholy of the animal's concluding notes. It commenced with an ardour that has something of military enthusiasm in it, but suddenly, as if the memory of secret griefs had supervened, the voice drops from the full-breathed outcry that rings across the Bikaneer wastes to a dolorous pumping up of hollow groans and husky sobs.' Pope speaks of ' the loud clarion of the braying ass,' and Swift called the donkey ' the nightingale of brutes,' but others have been less flattering in their references. Thus we read of ' the hard dry see-saw of his horrible bray.' Of Cowper's remark on the ass that frightened John Gilpin's horse, that it 'did sing most loud and clear,' Robinson says that ' this is the nearest approach to appreciation of this great jest of Nature that I know of in verse.' In any case, the earth will be a duller place when there are no more donkeys left to bray.

The interpretation of the extraordinary hee-haw is, of course, to be found in the donkey's ancestral home, which is the desert. The resonant call is adapted to wake the echoes of the great spaces. A loud-speaker is required in the sparsely populated dry steppes. When the donkey rolls in the dry dust, its Unconscious is recalling the desert; and perhaps a similar interpretation may be found for its frequent objection to stepping over a streamlet that crosses a road. Its colouring is often suited to a sandy background, where it is inconspicuous even to a lion's hungry eyes. Every one knows that a donkey becomes invisible on a common at night. Though we hear it eating, we cannot see it at all. The long ear is connected with the resonant bray, for it is adapted to catch a distant note of news in the boundless desert. In its mobility it also helps the sentinel of the little herd to locate the approach of the enemy. Not that wild asses relegate to others much of their individual vigilance, for they do not take many mouthfuls without raising their heads, searching the environment with their ear-trumpets, and sniffing the air. Wordsworth was peculiarly prosaic that day he saw the ass,

with motion dull,
Upon the pivot of his skull
Turn round his long left ear.

Another of the clear reminiscences of the desert home is the donkey's ability to thrive on very Spartan fare. Thistles recall the xerophytic vegetation of the arid lands where its ancestors are still at home. It is sad, however, that man should have taken advantage of the donkey's frugality and made it an excuse for not giving the creature enough to eat.

The African wild ass is a handsome, agile, high-spirited, courageous creature. It lives in little bands — usually a male and several females with their foals. Like other polygynists the males fight savagely with their rivals. As is the case with many other big-brained mammals, the young asses are very playful. They are irresistible combinations of roguishness and confidence, and there seems to be no warrant for calling them untamable. It is likely enough that the well-known Old Testament description of the wild ass referred to the Asiatic onager, but it would also fit the North African species.

Who sent forth the wild ass free?
And who loosened the bonds of the mustang,
Whose range I made the steppe,
And his dwellings the salt marshes?
He laughs at the roar of the city;
The shouts of the driver he does not hear,
He explores the mountains, his pasture,
And searches after everything green.

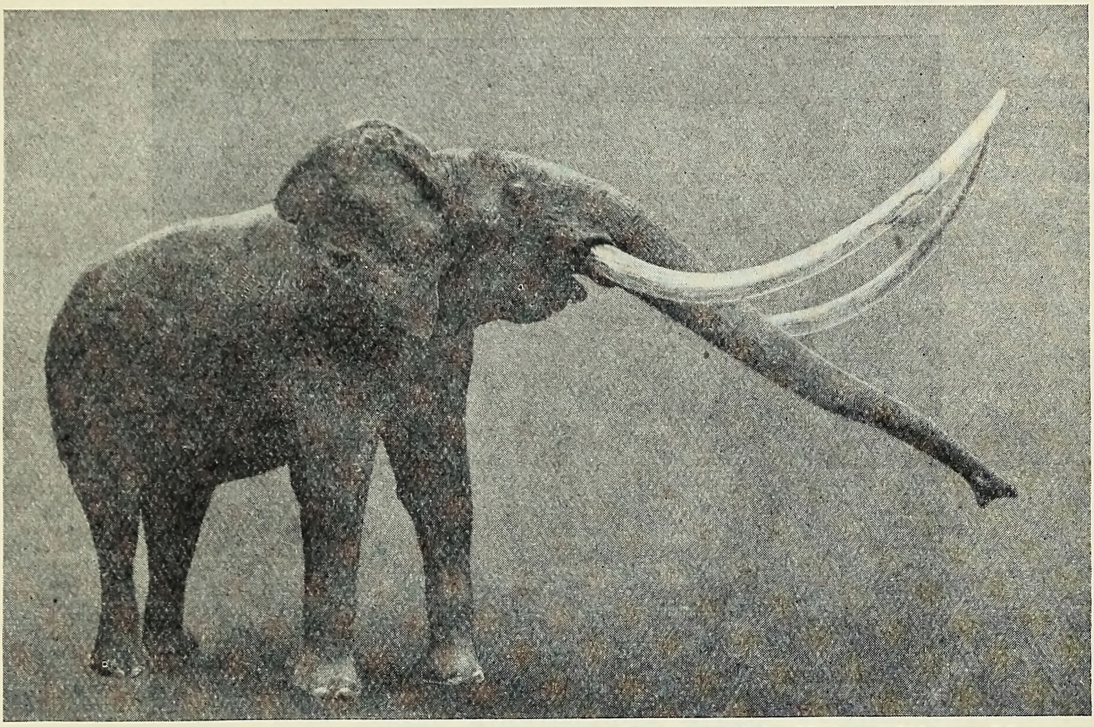
If the wild ass is such a fine creature, how do we account for the often depressed donkey? The depression is not to man's credit, but happily it is far from being universal. In many countries the domesticated donkey retains many of the good qualities of the wild ass. It is possible that some of the very dull dwarf types, 'not much larger,' as Darwin said, 'than a Newfoundland dog,' are semi-pathological variants, with perturbed endocrinal glands. But perhaps the main fact is that the dwarfish, depressed donkey is a diagram of the combined result of careless nurture on the one hand (including food, stabling, grooming, and treatment) and careless breeding on the other. We should photograph a dull 'cuddy' side by side with a high-caste white ass from Egypt, and label the picture 'Bad-breeding' and 'Good-breeding.' When we see a weary, disheartened 'moke,' we feel as if we shared in a breach of trust. It will be a sad pity if the fine type of donkey disappears from the haunts of men, and we will not be consoled by any car, bray it ever so imitatively.

The Elephant

African and Indian elephants (*Elephas africanus* and *Elephas indicus*) are two distinct species, or perhaps they are even further apart. The African form stands about a foot higher and has much larger ears; the line of its back is concave, not convex, and the forehead slopes more markedly backwards than in the Indian; the trunk has two finger-like processes at the tip instead of only one; the tusks are heavier and the worn surface of the molar teeth shows lozenge-shaped areas surrounded

by enamel. The African elephant is more energetic than its Indian cousin, less afraid of the sun, and more of a tree-browser. It has not proved to be so readily tamable, but some success has rewarded the patient attempts of recent years (see p. 747).

In his *Stalking Big Game with a Camera* Mr. Marius Maxwell tells how in park country in Kenya he came across a herd of between eighty



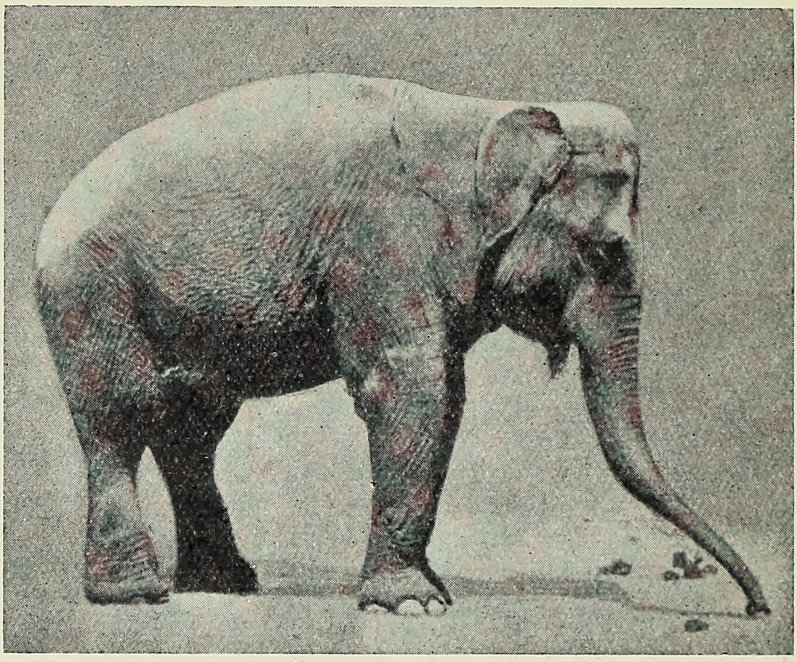
Courtesy of the Natural History Museum

FIG. 298. AFRICAN ELEPHANT

and a hundred elephants, consisting of bulls, cows old and young, and numerous calves of diverse ages and sizes. Moving from one cover to another, he got within seventy yards of the writhing mass of excited giants. He listened to the deep droning noises of the herd, like the beating of muffled drums, and to the intermittent shrill shrieks and loud trumpetings of cows anxious for the safety of their young. He saw in the sunset light a small ' forest of raised, poised, or gently swaying trunks, their lines here and there crossed by a gleaming white tusk.' He watched the swaying, congested crowd and the terrified young ones wriggling in between the legs of the adults. A charge seemed imminent, but after a threat or two the herd slewed round into an irregular column and slowly disappeared into the scrub.

Apart from extraneous noises such as the snapping of leafy branches, apart also from non-vocal sounds such as the loud chewing and munching or the flapping of the ears on the withers, there are many

elephantine sounds. A low squeaking from the mouth, rarely heard in solitude, is an expression of contentment; and so is a low purring rumble, apparently from the throat. This is sometimes uttered by a courting bull on approaching his desired mate. A careful listener to a mixed herd will hear: (1) a short and distinct roar of resentment or sometimes of fear; (2) a shrill cow-trumpeting, expressing resentment or anxiety; (3) shrieks from the cows to warn off their unruly calves;



Courtesy of the Natural Hist. Mus.

FIG. 299. INDIAN ELEPHANT

(4) a long-continued throaty rumbling from the herd when there is apprehension of danger; and (5) short coughing sounds and other throaty sounds made by the calves to their mothers. Baby elephants squeal when terrified, and they creep instinctively under the bellies of their mothers, thus effacing themselves in a gathered herd.

We incline to think of giants as callous, but the elephant is thrilling with sensitiveness. The tip of the trunk is a delicate tactile organ, and even the cushion-like pads in which the fingers and toes are embedded are sensitive to the feel of the ground when the leader is moving in a difficult place at night. With their trunk (a strange structure representing an elongation of the nose and part of the upper lip) they will pull down a tree, previously broken by pushing with their tusks, and with the trunk they will kiss one another. Filling the lower eighteen inches or so of the trunk with water, they discharge it into the mouth or splash it over the body—though the babies suck with their

lips. Associated also with the trunk is the keen sense of smell, which enables elephants to detect the presence of a white man at a distance of two miles, on the wind side, and to gauge his gradual approach with remarkable accuracy. They hear with ease even minute sounds like the click of the camera, and with their eyes they are quick to detect at thirty yards or so little novelties or rapid movements that have significance. Thus we must credit African elephants with a fine equipment of sense-organs, the value of which is enhanced by the well-developed brain that lies behind them.

We have already remarked that animals are not usually cleverer than they need to be, and although we know from the Indian elephant that the potential sagacity can be utilized when there is need or reward, it is not often called upon in natural conditions. Food is abundant everywhere and enemies are few. There is no great strain on the intellectual faculties, and elephants tend to be creatures of routine. The chief business of life is to keep the capacious stomach filled with grass and herbage, together with twig-ends and young shoots, tender tree bark, and fruit of all kinds.

In the headlong stampede, when the herd becomes panicky and charges, there is an instinctive avoidance of collision with trees and stumps. So what the surprised observer has to do is to stand behind a thorn tree and watch the excited giants rush past. But the observer requires some nerve, Mr. Maxwell says, when he sees the members of a large herd ' unconsciously bearing down straight in his direction, with ears extended, trunks poised in front of their immense chests, their quick-bobbing heads growing rapidly in size, and their gigantic bodies foreshortening with each approaching stride.' The intermittent deafening shrieks and shrill trumpetings and the beat of the ponderous feet are also rather trying to the nerves.

THE ELEPHANT AT THE PLOUGH.—Although Hannibal used the African elephant in war and the Carthaginians used it in peace, the belief is still strong that *Elephas africanus* differs from *Elephas indicus* in being untamable. But this is an error, as experience in zoological gardens proved long ago. The point has recently become of practical interest, for during the last twenty years the experiments of the Belgian Government in the Belgian Congo have shown that the giant may become a very useful servant on the farm. Especially since 1921 it has been found practicable to capture young elephants and train them to make themselves useful. The captives must be well under ten years old, but this is just a child's age for the elephant, which may live to be a centenarian. Now that taming and training are established facts, those that have acquiesced are used with much effect in the capture of young recruits. Humane and well-thought-out treatment has been richly rewarded. Working from 5 a.m. to 11 a.m. an elephant can plough

two and a half acres in two days. It can be used for collecting and piling timber. Two of them can draw a farm cart with a load of five tons. The cost of maintenance is low, for the elephant likes rough herbs, twigs, leaves, and roots, which are everywhere available. Maintenance, including the pay of two men to look after ' My Lord,' besides harness, food luxuries, and other extras, works out at a little over a shilling a day. So the African elephant is far from being a white elephant.

Tree-shrews

The little tree-shrews that range from India to Java are not much to look at, but they are extraordinarily interesting zoologically. They point in two directions, for they are primitive and yet they are pioneers. On the one hand, they show definite affinities with the South African jumping shrews (*Macroscelidae*), which are remarkably primitive mammals, harking back to marsupials. On the other hand, the tree-shrews reach forwards towards the ' half-monkeys ' or lemurs. In other words, they come near the base of the stem of the aristocratic Primates—the monkeys and apes. As the tree-shrews are for the most part arboreal, they exhibit features which are adaptive to this mode of life, and these must not be much attended to in trying to decipher relationships with other mammals that also live on trees, as the lemurs do. Quite different types may be superficially like one another because they are similarly adapted to similar conditions of life, but real affinity must be based on resemblance in much deeper characters, which may have little or nothing to do with the habits and habitat. Thus swifts are not related to swallows, though they are adapted to a somewhat similar mode of life and kind of food. The limbless lizard called a slow-worm is superficially like the limbless blindworm, but they are not related to one another, the former being a reptile and the latter an amphibian. The resemblances between tree-shrews and lemurs, however, are fundamental as well as superficial.

There are two genera of tree-shrews, *Tupaia* and *Ptilocercus*, which seem to be very unlike one another in their habits. We shall begin with *Tupaia*, which is better known than the other. There are several different species, living on the trees or among the fallen branches and stems on the floor of the forest. They are graceful and bushy-tailed, somewhat like squirrels, especially like a particular long-nosed squirrel called *Sciurus laticaudatus*, which prefers to keep on or near the ground. The resemblance, though quite superficial, is very close, and it has been suggested that the insectivorous tree-shrew trades on its likeness to the more innocent rodent squirrel.

In other words, there may be a kind of **mimicry.** An examination of the teeth shows at once that the tree-shrew has the cusped back teeth characteristic of hedgehogs, moles, shrews, and other insectivora, whereas the squirrel has the chisel-edged front teeth that we see in rats, rabbits, guinea-pigs, and all other *Rodentia.*

The suggestion of a squirrel is emphasized by a common attitude of the tree-shrew, for it often sits on its haunches and holds its food in its paws in the familiar squirrel-like fashion. But the food consists of insects and fruits, not of hard nuts and the like. Tree-shrews are shy, elusive mammals, but they are known to be very much on the spot and to be very agile in their movements. They may be called not only alert, but vivacious.

As there are many other lively mammals scattered over the earth, why do we single out these tree-shrews? The first reason is, as we said, that in skull and dentition and limbs Tupaia exhibits affinities with the lemurs of Malaya. The second reason is that they are the humblest mammals to indicate a trend of evolution which led on to man. The tree-shrews are the residuary legatees of a very progressive stock that probably led on to monkeys. But this requires a little explanation.

The cortex or rind of the mammalian fore-brain or cerebrum shows a great advance on that of birds and reptiles. It is such a new thing that Sir G. Elliot Smith proposed some years ago to give it a special name—'neopallium.' The newness consisted in this, that the cortex of the mammalian cerebrum received impressions from all the sense-organs—visual, acoustic, gustatory, and tactile, as well as olfactory; that its different territories were so linked together that a greater discrimination and yet unification of experience became possible; and, furthermore, that a special motor area was differentiated to receive tidings from muscles, tendons, and skin, and also to control responsive movements, especially those of a manipulative character.

Now the particular interest of tree-shrews is seen when their brain is contrasted with that of their cousins, the jumping shrews. As Sir G. Elliot Smith points out, 'the jumping shrew has a very primitive brain with a relatively enormous olfactory apparatus, because the animal's behaviour is dominated by smell. The patchwork of cortical territories constituting the neopallium includes diminutive areas for the reception of visual, acoustic, gustatory, and tactile impressions, and for the control of skilled movement.'

But when an animal becomes arboreal it means the emancipation of the fore-limb from being a supporting and levering structure to be the bearer of a free hand for testing and probing, reaching and grasping. It means a reduction of the snout and more room for a big brain; it means forward-shunted eyes and more stereoscopic vision. So in the tree-shrew, as contrasted with the jumping shrew, the olfactory area

is reduced, and there is a relatively enormous enhancement of the importance of vision, hearing, touch, and skilled movement. It cannot be said that Tupaia went very far, but it took a step which was followed by the spectral tarsier and by the lemurs, by the marmosets and the monkeys, and so on upwards. The anatomists can produce an eloquent series of brains showing the gradual predominance of the visual area, and the gradual growth of the pre-frontal region—the seat of attention, for instance—which comes to its own in man. The great interest of the tree-shrews is that they represent the first clearly defined step towards the human brain.

Mr. W. E. Le Gros Clark has given an admirable anatomical account of the very rare pen-tailed tree-shrew (*Ptilocercus*), which is confined to Borneo and the Malay Peninsula. It is a large-headed, big-eyed, soft-furred, elusive animal, about the size of a half-grown rat, with a somewhat quill-like tuft of hair at the end of the scaly tail. It hops on the ground, holding the terminal tuft almost vertically; it climbs with great skill, helped in its grip with its long curved claws. 'It climbs a door with ease, upwards, sideways, round the edge, and head downwards.' It makes a nest in hollow branches and lives on a mixed diet of insects and fruit. It is made very uncomfortable by the light, so it sleeps by day and is crepuscular or nocturnal in its activities. It sleeps on its side with its snout on its breast, the hind-limbs bent forwards, and the tuft of the tail usually covering the snout and part of the face, perhaps to keep off mosquitoes and flies.

Mr. Le Gros Clark's careful study of the structure of the pen-tailed tree-shrew (*Ptilocercus*) shows that it is much more primitive and generalized than the ordinary tree-shrew (*Tupaia*). It does not come so near the lemurs. The brain is much more primitive, with a large olfactory region. The visual regions are poorly developed compared with Tupaia, while the auditory centres are distinctly better developed. Here we see the advantage of some knowledge of the animal's habits, for it seems clear that the pen-tail has adopted nocturnal habits, specializing in the direction of auditory, not visual acuteness. The probability is that the pen-tail and Tupaia represent two successive phases in the evolution of a lemurid from a primitive insectivorous stock, and that the pen-tail lagged because it could not keep its face to the light.

The Character of the Orang

Galen, who died about A.D. 200, is said to have dissected the orang as a substitute for man, but not much was known about this great Asiatic ape till the middle of the seventeenth century—a typical instance of that long-lasting lapse of curiosity about Nature which

we designate the Dark Ages. This scientific apathy is being atoned for nowadays, when the anthropoid apes are rapidly becoming familiar friends. Of this keen and critical interest the finest recent illustration is the work of Professor and Mrs. Yerkes on *The Great Apes* (Oxford University Press, 1929).

The orang stands rather over four feet in height, and is massively built, short-legged, long-armed, thick-necked, pot-bellied. With increasing age the skull loses its youthful suggestiveness of the human, and becomes markedly snouted, pointed, and crested. Very characteristic is the reddish-brown hair that covers the whole body except the face, the short ears, the palms, and the soles. Some individuals show conspicuous crescent-shaped cheek-pads of unknown significance, unless they betoken masculinity; and another peculiar feature is a fold of naked skin which hangs down below the chin and covers a pouch from the voice-box or larynx. It may be that this pouch functions as a resonating sac, deepening and augmenting the volume of the voice. The brown eyes are lively and expressive; the lips are very mobile; but the attractiveness of the young orang is gradually coarsened, and to most impartial observers the full-grown ape verges on the repulsive.

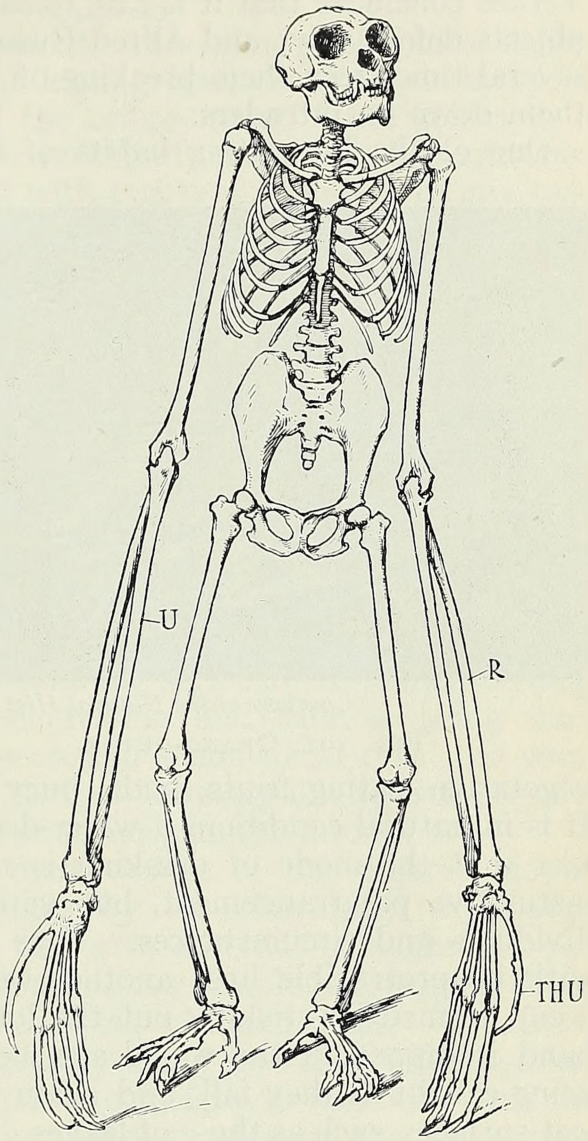


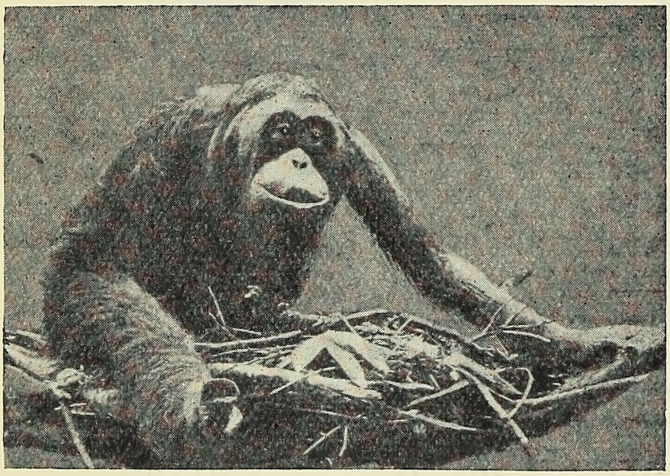
FIG. 300
SKELETON OF AN ANTHROPOID APE
R, radius; U, ulna; THU, thumb.

There seems to be only one species of orang-outan, *Pongo pygmaeus*; but it displays much variability—indeed, individuality. The female is smaller than the male, and the proportions of the body are different. The geographical range is restricted to Borneo and Sumatra, and the favourite haunt is the swampy forest.

One orang-outan may differ widely from another in activity, but the

average is sluggish. They are children of the trees, but as cautious as the gibbons are daring. Only for a short distance can they walk erect, and they seem to find it difficult and fatiguing. They show great disinclination to enter the water. After careful scrutiny Professor Yerkes concludes that it is safe to say that some orang-outans throw objects defensively; and Alfred Russel Wallace reported that he had several times seen them breaking off pieces of branches and throwing them down on intruders.

One of the interesting habits of the orang-outan is nest-making. A platform of branches and other materials is rapidly built at varying heights on a tree, sometimes perhaps for concealment, but usually as a bed. The ape sleeps on its side or on its back, and the 'nest' is sometimes fashioned so that the sleeper is protected from the dew and the cold. There is ample evidence that orangs often snore.



Courtesy of the Natural Hist. Mus.

FIG. 301. ORANG-OUTAN

The orang-outan is a vegetarian, eating fruits, buds, juicy shoots and leaves, and so forth. It is in natural conditions a water-drinker, and there is interest in the fact that the mode of drinking is not prescribed by an inborn or instinctive prearrangement, but varies considerably in different individuals and circumstances. Thus one ape will suck up the water with its protrusible lips; another will allow rain-water to drip into a cup formed by sticking out the lower lip; on another occasion the hand is dipped in the water and held above the mouth, the drops being caught as they fall; and again there may be a simple licking of wet surfaces, such as those of leaves. This diversity points away from stereotyped instinctive behaviour and towards intelligent profiting by experience, as in mankind.

Speaking of water makes us think of cleanliness, and the mother orang's parental care includes scrupulous attention to her offspring's body. This experience becomes an individual habit, and cleanliness is characteristic of the adult orang. In inadequate housing, however, captive orangs may relapse into carelessness, since it becomes too difficult to be cleanly. This is interesting, for, as Professor Yerkes says, it is paralleled in human behaviour, 'where a bad environment

discourages the development of good personal and social habits, or tends to break them down, even if well established.' This line of thought is often ignored by those who seek to draw between hereditary 'nature' and environmental 'nurture' a hard-and-fast distinction which forgets the unity of the organism.

There is food for thought in the fact that the same geographical region is tenanted by the most and the least gregarious of the anthropoid apes—namely, the gibbons and the orang-outan. This points to a difference in temperament, for the social and the individualist solutions are in this case equally rewarded with practical success. In any case it is certain that the orang-outan is one of the each-for-himself types, self-contained, independent, individualistic, except within the family circle. The adult male orang lives as a solitary except at the breeding season. Two or three old females may be found together, but in most cases the unit is the family—a mother with a baby and a toddler. As far as can be gathered from the scanty reliable information, orang-outans are easy-going, friendly, placid creatures. They are the reverse of quarrelsome, unless they fall into bad health in conditions of captivity. Some quaint observations record that an orang threw missiles at its unrecognized reflection in a mirror, becoming indignant because the other fellow refused to play up.

Very little is known in regard to the inner life of orang-outans. They are inclined temperamentally to take life seriously, and their feelings incline to be grey in colour—depression and sadness being most characteristic. As might be expected in a non-social type, the vocabulary is short; and there is no hint of language in the true sense of expressing a judgment by means of socially imitated sounds.

Of their genuine intelligence there cannot be the slightest doubt. They learn to do effective things by experimentally eliminating ineffective tentatives, but they also give external evidence of 'perceptual inference'; that is to say, of making simple judgments. They adapt their behaviour without requiring to make trials. They have not 'Reason,' but they can *reason*, putting two and two together. They show 'a measure of understanding, insight, or ideation'; and this is one of the new conclusions of the twentieth century, that the anthropoids are much nearer us intellectually than even Darwin believed. But even when we compare the orang at its best with man at his worst there is a difference in kind; for the orang does not possess the capacity for conceptual inference, or playing with general ideas, which we call Reason.

The Gorilla: A Very Distant Connection

The gulf between the gorilla and modern man is immense, yet the gorilla is, anatomically regarded, our nearest *living* relative. To omit

the word ' living ' would be altogether fallacious, for the gorilla is not on the direct line of man's ancestry. The apes are on collateral branches, and our nearest relatives are to be sought not among them, but among the long-lost common ancestor of Neanderthal man and *Homo sapiens*. So we must not think of gorillas and chimpanzees as poor relations to be ashamed of; ' very distant connections,' as our aunt used to say of our adventurous second cousins. More scientifically, they must be regarded as remote relatives on a different branch altogether — simian not humanoid, which have evolved towards brawn, as we towards brain.



Courtesy of the Nat. Hist. Mus.
FIG. 302. GORILLA

Moreover, whatever be man's pedigree, when he came to his own he was a new synthesis. In Lloyd Morgan's phraseology, man illustrates **emergent evolution**; he probably arose as a genius or mutation, even more different from his forbears than Aristotle or Archimedes, Shakespeare or Newton, from their fellows. For man stands apart from all the beasts of the field: (*a*) in his language (as contrasted with mere words); (*b*) in his reason or power of conceptual inference (as contrasted with intelligence or perceptual inference); (*c*) in his more or less clear awareness of his own history; (*d*) in his capacity for controlling his conduct in the light of ideals; and (*e*) in building up an external or social heritage, transcending the natural inheritance which has its vehicle in the germ-plasm. So without slackening our conviction of man's solidarity with the rest of creation, we hold firmly to the fact of his unique apartness.

In one of his Hunterian lectures Sir Arthur Keith drew an anato-

mical contrast between gorilla and man, and his expert conclusions are of great interest. As regards gait, to begin with, the gorilla, sometimes weighing thirty stone, is too heavy to be much of a climber. It keeps mainly to the ground, supporting and balancing its weight on its bent knuckles as it waddles along, and using its foot as a supporting and propelling structure, with the great toe in alignment with the others. Yet it scrambles in the bamboo thickets in search of sappy shoots, and can then use its great toe as a grasping organ. Thus the gorilla's foot is in a striking way intermediate between that of the arboreal chimpanzee and that of the human child; flexion-lines like those of the gorilla's foot are to be seen on the sole of every newly born baby. The anatomist concludes that ' the human foot, in the course of its final evolution, passed through a gorilline stage.'

This is Sir Arthur Keith's pithy way of summing up the contrasted evolution of man and gorilla from a distant common stock. In size and pattern of brain the gorilla comes nearer man than does any other animal, and there are many detailed resemblances, in musculature for instance, which justify Sir Richard Owen's conclusion that there is ' an all-pervading similitude of structure ' between man and ape. Yet between the best gorilla brain and the worst human one there is a great gap, with nothing to fill it but the suggestions afforded by the fragmentary remains of *Pithecanthropus erectus* from Java. The human type forged ahead in brain improvement, the gorilla type advanced in weight of body, volume of lung, massiveness of jaw, and strength of muscles. Man is the climax in one direction—brain, the gorilla in another—brawn. Of course this is not *quite* fair, though, for our present contrast, justifiable; we must grant at once that the gorilla has a fine brain, far ahead of that of most of the beasts of the field.

It is interesting to note that the huge gorilla begins its post-natal life smaller than a new-born child, just as nude and helpless, with a skull as rounded and smooth, and with jaw muscles no larger. But the gorilla's advance towards *brawn* is soon very marked, whereas man lingers in body development and progresses in *brain*. In many bodily characters man remains more youthful than the gorilla, but in the end he lifts his head to the stars.

Sir Arthur Keith suggests an exceedingly interesting theory, that the gorilla's bodily peculiarities, as compared with man's, mark an increased activity of that part of the **pituitary body—a ductless hormone-making gland** below the brain—which influences growth. It is very striking that in the disordered action of the pituitary gland associated with the human disease called acromegaly there is an appearance of growth-changes similar to those that occur normally in the life-history of the gorilla. This fact, that a patient suffering from acromegaly shows gorilline or simian features, is startlingly

instructive, not only because it indicates a blood-relationship or derivation from a common stock, but because it points to one of the possible factors in evolution. A variation in the activity of one endocrine or ductless gland, such as the pituitary, may be followed by changes of structure in other parts of the body. The physician knows that something wrong with the pituitary gland, some pathological variation or modification, that is to say, has an influence on the growth of the muscular, bony, and alimentary systems of the living body; and these are the systems that undergo a great degree of increase during the later stages of growth in the gorilla.

'We may therefore legitimately infer that, in the evolution of the gorilla, the pituitary has played a prepotent part. The evidence, as it stands, is enough to justify the student of man and ape in believing that he has obtained a real glimpse into the machinery of evolution.' We dislike the word 'machinery' as applied to vital changes, and nothing of Sir Arthur Keith's meaning is lost if we change it into 'method.' More important, however, is it to recognize that the ingenious theory leaves us asking: *What made the pituitary body vary?* An accentuation of activity in endocrinal glands has been proved to have certain structural consequences, and a dwindling of activity has been proved to have others; but we are left facing the problem: *What made the endocrinal glands vary?* Plus and minus variations are indeed common among living creatures, a little more of this and a little less of that; yet as regards the causes of this ebb and flow of the living tide, we must still confess with Darwin that 'our ignorance is immense.'

END OF VOL. I

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